Union Calendar No. 920

86th Congress, 2d Session - - - - - House Report No. 2078

OCEAN SCIENCES AND NATIONAL SECURITY

REPORT

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SIXTH CONGRESS

SECOND SESSION

Serial h

July 1, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

UNITED STATES
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56612 WASHINGTON : 1960

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LETTER OF SUBMITTAL

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C., July 1, 1960.

Hon. Sam Rayburn,
Speaker of the House of Representatives,
Washington, D.C.

Dear Mr. Speaker: By direction of the Committee on Science and Astronautics, I submit the following report, "Ocean Sciences and National Security," for the consideration of the 86th Congress. At a meeting of the committee on June 30, 1960, the report was adopted and approved for submission to the House.

It is believed that this report represents a real landmark for its scope and thoroughness in coverage of subject matter, and will serve as a useful source to all committees of the Congress and executive branch agencies concerned with the problems of the ocean sciences.

Overton Brooks, *Chairman.*

LETTER OF TRANSMITTAL

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C., June 10, 1960.

Hon. Overton Brooks,
Chairman, Committee on Science and Astronautics.

Dear Mr. Chairman: I am forwarding herewith for committee consideration a report, "Ocean Sciences and National Security," prepared by Dr. Edward Wenk, Jr., Senior Specialist in Science and Technology, Legislative Reference Service, Library of Congress.

On April 28 and 29, 1960, this committee held hearings the record of which has been issued under the title, "Frontiers in Oceanic Research." This was in connection with H.R. 6298, a bill pending before the committee. Dr. Wenk worked in collaboration with Dr. Charles S. Sheldon II, Technical Director, developing the plan for the hearings. In view of Dr. Wenk's background in design of deep-diving submarines and general knowledge of the naval sciences, he was requested to develop a study which would both reflect the findings of the two days of hearings, together with material submitted for the record, and provide a broader view which would give the committee a better perspective of the scientific research needs in this area. As a committee charged with responsibility across the board for considering the research and development programs in all fields of science, a study such as this can be of real help in judging the alternative distributions of the available research funds among all fields of science.

Dr. Wenk and the committee appreciate the cooperation of responsible scientists in Government, the National Academy of Sciences, and in private universities for their review and suggestions given the manuscript and galleys before final printing. Although most of their suggestions have been taken into account, they cannot be held accountable for the details of the report. The report has also been reviewed by Dr. Sheldon. The committee expresses its thanks to the Legislative Reference Service for the thorough job which has been performed.

The main body of the report, Sections I–XIII inclusive, is what is referred to above. Committee staff has appended Section XIV, Committee Conclusions and Recommendations, for possible adoption by the committee.

Charles F. Ducander,
Executive Director and Chief Counsel.

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OCEAN SCIENCES AND NATIONAL SECURITY

JULY 1, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. BROOKS of Louisiana, from the Committee on Science and Astronautics, submitted the following

REPORT

OCEAN SCIENCES AND NATIONAL SECURITY

I. Summary

With hopes for agreement on peaceful coexistence once again recently shaken, leaders of both political parties have noted that the United States faces a future full of uncertainties. They argue, further, that the only sure course of survival lies in a plurality of coordinated programs to develop our political, economic, and scientific resources as well as our military. In that context, the sea—which has historically served the United States in a dual role as a natural geographical barrier against aggression and as a medium of peaceful commerce—appears destined to be closely linked with national security. At the same time, the sea—which covers almost three-fourths of the Earth's surface—has remained almost completely unexplored. A major question, which through pending legislation is on the agenda of the 86th Congress, concerns how this Nation can best mobilize for a concerted long-range program of research and exploration of and in the sea.

Planning for the future now has the benefit of several comprehensive studies of the content and urgency of the needs for new information, and of the present posture of the United States in terms of its oceanographic research capabilities. Proposals have been formulated of specific steps to remedy what has been generally considered a neglect of the ocean sciences. The most incisive study was that undertaken by a new Committee on Oceanography of the National Academy of Sciences, which was organized in the Fall of 1957 at the request of several Government agencies that recognized the problem and had jurisdiction over oceanographic research. A second independent study was undertaken by the Navy Department itself and a third, more recently, by the Interagency Committee on Oceanography.

All concur on the vital significance of the oceans to the national welfare and on the disproportionately small fraction of our national scientific resources in terms of manpower and funds that is now devoted to oceanic research. Proposals were outlined in considerable detail to accelerate this effort promptly, such that the level of effort 10 years hence would be roughly 3 to 4 times that at present. These proposals involve Federal expenditures at that time of approximately $85 million per year in contrast to the 1958 base used for the study of $24 million per year. According to these proposals, an even higher rate of appropriations during this 10-year interval is recommended to replace obsolete and overage research vessels, frequently converted from fishing trawlers, that now characterize the research fleet.

Only 1,600 junior and senior scientists are now engaged full time in oceanic research, and considering the scope of subject matter and

geographical dispersion of the medium under study they appear thinly spread. Without exception, these studies have called attention to the serious problems in developing an adequate supply of trained manpower.

All of the proposals anticipate sharply increased fiscal requirements from Federal sources, as well as increased responsibilities of executive agencies for a national program of research, both military and nonmilitary. Because these proposals are so far reaching, and especially where questions are raised of means for interagency coordination, committees of the Congress having jurisdiction have undertaken to examine the problem independently. A number of hearings have been conducted to develop background information; a number of bills are yet pending. The major issues before the Congress mainly concern Federal organization and appropriations to support the proposed effort.

Apparently there is agreement by members of the scientific community, by officers in executive agencies having jurisdiction, and by various leaders in the Congress that the present program must be expanded. This particular report summarizes the arguments given in support of this view and of the present sense of urgency in terms of—

(*a*) The Soviet submarine threat from the sea.

(*b*) The need to survey, study and develop biological and mineral resources in the sea which, before long, may be required to supplement rapidly depleted continental resources; this includes both fish that could be a significant source of protein for human consumption, and minerals.

(*c*) The significance of research to develop new knowledge about the sea, particularly in light of contemporary events which make scientific achievement an element of public affairs; considering the present lack of knowledge, the statistical possibility exists of breakthroughs in terms of basic information as well as potential applications.

(*d*) The desire for basic scientific information such that man may gain clues concerning the origin of the Earth necessary for an understanding of other planets which he plans to explore and of the evolution of life itself. A better understanding may be developed of the relationships of the ocean to climate as a basis for long-range forecasting of climate and even its eventual control.

(*e*) The need to develop information to assure safety of disposal of radioactive waste which man has chosen not to accumulate on land.

The report further inventories the existing capabilities in oceanographic research, in terms of universities and other laboratories undertaking oceanic research, manpower, the size and sources of funds especially from Federal agencies, including the manner in which Federal programs from some 19 different agencies are integrated; and, finally, the manner in which the United States participates in international programs. Comparisons drawn with Soviet oceanography show a trend of emerging Soviet superiority in both size and content of program.

The three different 10-year plans are abstracted, compared and analyzed, and attention drawn to implications in which the Congress may have a particular interest. Finally, pending legislation is summarized as are those issues before the Congress.

It is increasingly clear that the Federal Government will play a dominant role in both the leadership and funding of any national

program in oceanography. The major questions before the Congress are to evaluate the degree of urgency, to identify national goals if these are deemed warranted, and then to decide how best to organize to achieve these goals promptly, effectively and with due concern for thrift. Committee conclusions and recommendations are given in Section XIV.

II. Background and Scope of This Study

During the past 2 years, United States activities in the field of oceanography have been discussed, dissected, evaluated, and publicized more thoroughly and more deliberately than at any time in the history of that science. The measure has been taken of the size and scope of our current nationwide effort; future needs in light of contemporary threats to national security have been identified; proposals have been formulated and advanced for immediate acceleration and invigoration of the program. News media and professional journals, alike, have carried an unprecedented number of authoritative articles on the current state of oceanographic affairs. The 86th Congress has had placed before it eight different bills representing legislation with the intent of assuring enhanced national posture in oceanography, by increased emphasis on education and training, by identification of scientific goals, by formulation of a unified national program and by establishment of a statutory base for coordination of those Federal agencies concerned.

The question might well be asked as to what factors have stimulated such unusual attention to an old and honored but relatively small branch of the sciences. Especially it might be asked, what has prompted this sense of urgency sufficient to elicit study, investigation, and planning at the highest echelons of Government?

At least four such influences can be readily named:

(*a*) The undersea threat to our national security;

(*b*) The emerging significance of science and technology as an instrument of world affairs;

(*c*) The potential of the sea for greater international understanding and cooperation; and

(*d*) The eventual worldwide exploitation of ocean resources.

What underscores each of these factors is our relative ignorance of the sea and its contents, and of the recent evolution of technologies which have now made the sea assume a new significance, but which have also rendered the sea more susceptible to systematic exploration.

The potential of oceanography assumes a special importance for the United States. The oceans have had an exceedingly vital, if subtle, impact on our military, economic, and political history. Essentially a geographic island, the United States found the seas a protective barrier providing a stability to processes of growth and a monopoly on our continental resources that fostered eventual accession to a position as a world power.

Now, however, the oceans reveal themselves as no longer impenetrable—a very real threat lies in the Soviet submarine fleet far more numerous than ours that, concealed by the opacity of the sea, could approach our shores and, still in international water, launch a shower of intermediate-range missiles. The surveillance of the sea: to detect, to classify, and to monitor any such hostile vehicles, is one of the most critical ingredients of any program of antisubmarine warfare. To find such targets requires a far more extensive knowledge

of the sea itself than currently prevails. The first and most compelling stimulus of attention to oceanic research is purely military.

The second factor of aroused interest is purely scientific—that is, the need to fill a major gap in knowledge about our own planet. To use a much-worn phrase, more is known about the Moon than is known about the oceans (which cover 71 percent of the Earth's surface) their contents, and the floor beneath. Man's restless curiosity about the world around him might well serve as an intellectual basis for an increased program of research. But, in just the past 3 years, a new concept of science and technology has emerged which renders the conduct of research and the identification of scientific achievement a significant element in international affairs. In our relations with other countries, in our competition with the Soviet Union, scientific discovery and technological achievement, especially with peaceful applications in mind, have become as potent in attempts to attract the uncommitted countries of the world as the display of a new military weapons system. For the first time in history, the intangibles of international prestige hinge visibly on science and technology.

That we, as a nation, have reacted to the Soviet initiative in outer space is well documented by new legislation, decisions on funding, and by statements of national purpose. The budget for fiscal year 1961 for the National Aeronautics and Space Administration shows signs of approaching one billion dollars. Although in any circumstances activities in outer space would have been pursued, the major driving force has been derived from the initial lead by the Soviet Union. With that example, there is reason to contemplate further moves by the Soviet Union in other scientific fields, and with the U.S.S.R.'s capabilities of controlling scientific programs, she might well marshal her resources to make the oceans—the inner space—the next area of major activity.

It would be immature to believe that the United States could maintain leadership in all fields of science and technology, even if this were an avowed national policy. Nevertheless, the unexplored potential of oceanography is among the few areas specifically identified by national leaders as warranting special attention. In that regard, even if it were agreed that the United States should embark on one or more deliberate programs of scientific and technological endeavor as a matter of national policy, those concerned with governmental responsibilities and the general public itself have need for information and analysis on the basis of which their decisions could be intelligently made.

Still a third significant reason advanced for an enriched national program in oceanography lies in the matter of national self-interest through a better understanding of the resources in and under the sea. At the present time, the sea belongs to everyone and essentially to no one. Except for protection offered within the continental limits, whether these be 3, 6, or 12 miles, the high seas are owned in common but controlled and dominated by nations having the greatest sea power. One result of this "freedom of the seas" is the universal utilization of the surface for commerce. Nevertheless, there have been and still are international disputes of varying criticality concerned with fishing rights and these differences in viewpoint would surely be accompanied by a rise in temperature and possibly hostilities, if the property in dispute had even greater financial value.

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Resources in and under the sea are so little known that questions of eventual ownership seem remote. Nevertheless, without an inventory of these resources, there is no assurance that the problem will not arise, and in that event, despite the 1958 Geneva Convention which places sovereignty of the seabed in the hands of coastal states, claims for ownership of resources in the open ocean might well emanate from precedence in their exploitation. The country there first might well be able to establish a superior legal claim. To prevent these national rivalries from becoming inflamed, the oceans may some day be subject to the same sort of treaty now being considered for international control of the Antarctic. But there is some reason to believe that any such agreement depends on the United States holding some claim by virtue of its own explorations.

Still another reason for maintaining a position of scientific leadership in ocean research rests with the yet undeveloped biological resources in the sea. Many nations balance their economy on products derived from the sea. Large segments of the world population are fed from the sea. But in the face of population pressures, additional sources of protein for human consumption must be sought and the sea is held to offer an important palliative to this problem. Thus, as part of our program of international assistance and cooperation, the United States, through research in the sea, might well provide knowledge concerning the location and habits of fish, more efficient techniques of their capture, and even the possible systematic cultivation of life in the sea to help feed the hungry of the world.

In this perspective, research in the oceans has become a matter of more than ordinary concern to the Congress. The far-reaching military, economic, political, and scientific elements of oceanic research are of interest to a number of committees in both the House of Representatives and the Senate. All, however, have parallel interest in identifying, in as specific and concrete terms as possible, the current state and level of oceanographic research in the United States and some dimension of the need. On this basis, Congress, in carrying out its constitutional responsibilities, would thus be able to determine the extent to which research in the sea demands special attention, the question of whether existing statutory authority is adequate to assure steady progress toward research goals and if so the extent to which these current laws are being properly implemented. If statutory authority is inadequate, then reference is necessary to further background in order that corrective legislation be prepared.

This study has been prepared at the request of the House Committee on Science and Astronautics, particularly to provide such background information. The scope was intended—

1. To establish the perspective of oceanic research as an element in the national security.
2. To inventory present capabilities in oceanography.
3. To identify the nature and content of future programs that have been proposed by Government agencies and by scientists as a basis for a concerted national effort.
4. To analyze the need, the present size effort, and plans to increase that effort, as background to assist the Congress in determining the extent to which such programs will answer the needs.

5. To summarize those immediate and emerging issues before the Congress.

This report covers the potential of research in the sea. Not included are problems of marine biology and research associated with bodies of fresh water nor engineering problems concerned with rivers and harbors. Moreover, it was not intended that this background study be considered a critique of pending legislation. Those bills now pending in the 86th Congress are listed and the background interpretation in this report may be helpful in evaluating their need.

III. The Relationship of the Sea to National Security

The role occupied by the oceans in the destiny of any nation can never be completely isolated from other factors which comprise the geopolitical complex. Causal relationships between events can seldom be identified, either publicly or even within the secret archives of Government. Nevertheless, throughout the interval of recorded history, the vertical cultural evolution and the horizontal geographic dispersion of man have been inextricably linked with the sea.

It is beyond the scope of this current report to do more than recite some of the basic political, economic, and military entities which relate the sea to the affairs of nations, and in particular, the United States. With such background, a frame of reference can be established concerning present and proposed programs in oceanic research.

A. Historical Perspective

The sea reveals a dual, sometimes anomalous, character. On the one hand, it is a protective geographic barrier insulating and compartmenting human endeavor. On the other hand, it is an inviting medium of commerce and of communication. As a barrier, the sea has acted both as a military shield against aggression and for those continentally oriented nations, it has limited both expansion and trade. But, for those more imaginative and bold, the sea has fostered the march of empire. The movement of bulk goods on strategically located rivers or along coastal routes has long been favored over cumbersome and arduous movement through mountains or arid land. The use of the oceans for commercial intercourse, the subtle export of cultural influence and eventually deliberate settlement overseas to relieve domestic pressures are all logical extensions of the precursive use of short water routes.

Today, even with colonial empires evaporating, the oceans continue to serve international trade. Virtually no technologically advanced nation is so self-sustained as to lack the need for imports of either raw materials or special manufactured goods. No advanced nation is so economically independent as not to rely for a part of its income either on exports or, as in the case of Great Britain, the Netherlands, Greece and Norway, on profits from carrying goods of other nations in their merchant fleets. Even with the proliferation of railroads and highways, and the contemporary development of mass air transport, water is still far the least costly and most used medium for moving bulk cargo. [1]

The oceans have revealed a second economic influence—in the development of fisheries. Once a purely local occupation, this industry now entails large numbers of ships ranging far from their home ports. Equipped with modern engineering devices to navigate or even locate fish, success depends now more on scientific knowledge of fish ecology

[1] "A rule of thumb states that the cost of sea, land and air transport, as far as mass goods are concerned, stands in the relationship of 1/10/100." See: "Transportation: Basis of Power," A. E. Sokol, Marine Corps Gazette, October 1959, pp. 10–16.

and physical oceanography and less on tradition, superstition, and lore. Catches may be consumed at home or exported; they may also provide products other than food. For many nations, fisheries represent a significant element in the economy, either for income or as a source of protein for human nourishment.

While the merchant marine and fisheries characterize two peaceful applications of the ocean, it has had an alternative quality as an element in warfare. In offense, the oceans provided combat forces with flexibility and mobility in deployment, the freedom to disperse and concentrate rapidly, and to exploit the element of surprise that were far superior to geography-inhibited capabilities of land armies. To defend itself against a hostile fleet, a nation in the past had to literally fortify an entire coastline. Even then, a surprise assault at one point often pierced well-fortified positions, as was well demonstrated by the allied landing in Normandy. When a nation is extended over a large area of the world, other nations with control of the seas can cut communications with overseas possessions. Moreover, control of the sea by those nations with vulnerable coastlines is essential either to deter the intentions of a hostile nation or to blunt an attack. In the last two wars, the U.S. control of the seas was considered a significant factor in preventing enemy forces from reaching the mainland.

The entire history of the United States has continuously revealed an intimate relationship with the sea. While this relationship has undergone cycles of emphasis and deemphasis, contemporary events discussed by national leaders now appear to underscore its renewed significance in our national affairs.

During its infancy, the United States was protected by an ocean buffer behind which it was possible to develop a continent free of the distractions and dilutions which characterize growth in those countries having numerous contiguous neighbors. Even the first settlers of the original colonies were conscious of the ocean. At their back was a hostile wilderness such that their survival and security depended on a precious thread of logistic support 3,000 miles long.

Prosperity of the colonies depended heavily on trade, particularly the export of furs, tobacco, and other products. The seas provided this important medium of transportation, although initially all of these goods were carried in British ships. Under the incentive of the mercantile system, as well as pure self-interest, the American colonists soon built their own ships and entered foreign trade. Best known is the triangular route that New England developed with Africa, the Caribbean, and Europe, with cargoes of slaves, sugar, rum, and American products.

As long as the colonies were protected by the British political and economic system, they did not seek to develop either an independent navy for the protection of the merchant fleet or data about the ocean. After gaining independence, however, there was a great burst of maritime activity that included construction of the "clippers"; these prizes in naval architecture, together with war vessels proved during the conflict of 1812 that they could outmaneuver and outgun even the British. There was also an energetic development of treaties and agreements for breaking into the firmly developed monopolies on world trade. The freshly born U.S. Navy protected these lifelines.

Even so, to a great extent, the British Navy served as a guardian of the sea barrier and, for reasons of British foreign policy, made practicable U.S. enforcement of the Monroe Doctrine.

With independence, the new American Nation entered upon a course of nationalism which included a concentration of intellectual and physical efforts toward the interior. By the 1830's and 1840's "Manifest Destiny" was a widely accepted doctrine. That is to say, the Americans were destined to occupy, civilize, and populate the continental land mass between the Atlantic and the Pacific. Some Mexican territory fell before this urge to possess a continent; the British compromised on their claims to what is now our Pacific Northwest. Oratorical enthusiasm sometimes extended the scope of Manifest Destiny to all of the Western Hemisphere and all of the Pacific basin. These larger imperial visions failed of fruition but did lead to significant ventures beyond the territorial frontier. The principal importance of Manifest Destiny was that the efforts and focus of attention of the American people turned from the sea to the interior. The relationship of the United States with the sea became temporarily dormant.

This implication of national policy was reflected in a changing stature of the American maritime fleet. Its day of glory before the Civil War was based on wooden ships and sail. While the traffic on inland waterways converted quickly to iron and to steam, the overseas fleet, failing to find either commercial or Government stimulation, withered. Then, during the Civil War, the earlier trade patterns were completely disrupted and many merchant vessels were destroyed. Although well intentioned, the Federal Government adopted a series of measures which did not revive the merchant fleet in the face of vigorous competition, but in contrast, gave cash and land grants after the Civil War to encourage the development of railroads. American attention, once again, was focused on the heartland.

At the end of the 19th century, the U.S. merchant fleet reached a new ebb, a pattern clearly evidenced by the following table of the capability of the merchant fleet.[2]

Year:	*Tonnage*	Year—Continued	*Tonnage*
1789	123, 893	1880	1, 314, 402
1800	667, 107	1890	928, 062
1810	981, 019	1900	816, 795
1820	583, 657	1910	782, 517
1830	537, 563	1920	9, 924, 694
1840	762, 838	1930	6, 295, 935
1850	1, 439, 694	1940	3, 637, 617
1860	2, 379, 396	1950	8, 353, 000
1870	1, 448, 846	1958	6, 208, 000

The disastrous effect of the Civil War and the decades of neglect afterwards are readily apparent. World Wars I and II obviously stimulated the expansion of the American merchant marine. Yet in 1958, only 13.6 percent of the total import and export cargo tonnage of the Nation was carried in vessels flying the American flag.

Just after the Civil War, Rear Adm. Alfred Thayer Mahan wrote an important treatise reminding the American people of the critical role of seapower in history and its particular significance for the United States. Mahan started from the fact obvious to any viewer

[2] "Historical Statistics of the U.S., 1789–1945," and "Statistical Abstract of the U.S. 1959."

of the international scene in the latter decades of the last century—Britain's supremacy on the sea and the strength of its empire. Mahan explained this phenomenon in terms of the impact of seapower: "Production, with the necessity of exchanging products, shipping, whereby the exchange is carried on, and colonies, which facilitate and enlarge the operations of shipping and tend to protect it by multiplying points of safety" are the three things in which "is to be found the key to much of the history, as well as the policy, of nations bordering upon the sea." From these premises Mahan showed how the geographical positions, physical conformation, extent of territory, number of population, character of the people, and the character of the government all in concert determined how nations responded to the challenge of seapower. To his analysis, for example, a geographic situation that avoids the need for land defense or extension is preferable. Therefore Britain, an island group, had an advantage over France and Holland. The United States occupied somewhat the same position relative to Eurasian powers. Inspired in part by Mahan, Theodore Roosevelt sent the "Great White Fleet" on a round-the-world cruise, effectively utilizing the "show of the Flag" to dramatize the true status of the United States as a great power. Part of the drive for an Isthmian canal also derived from Mahan's observations of the grave consequences of a split naval force as in the case of France with its Mediterranean and Atlantic fleets.

Although the revival of the Navy started before the Spanish-American War, that conflict suddenly thrust the United States into possession of land overseas and generated an entire complex of new functions: construction of coaling bases on the way to outlying possessions; development of shipyards, armour plate works, and ordnance plants; hydrographic surveying of unfamiliar ocean areas; and the growth of an ideology to explain and orient all the new activities. Development of ideologies is not an American specialty. Rough-and-ready pragmatic formulations are more in the American style. To some extent, Mahan provided an intellectual foundation. But the American position vis-a-vis the oceans was largely in terms of defense, narrowly construed. The United States was a continental island, as it were, that could only be effectively attacked by aggressors coming over the oceans. The Navy, our "front line of defense," was to be second to none. With the rise of Japanese seapower, that meant a two-ocean navy.

Our World War I experiences underlined something very well understood by Mahan: merchant tonnage in being was necessary to take advantage of the logistical flexibility provided by waterborne transportation. Federal policy since then has led to a revival of the merchant marine. During World War II, the significance of merchant tonnage was again underlined. Today the widespread use of "flags of convenience" obscures the heavy national dependence on a merchant fleet for peacetime use as well as a standby resource during war.

The positive influence of merchant shipping as a commercial and military entity in the strength of nations is matched by its negative qualities—vulnerability. This became manifestly clear in the First World War when German U-boats destroyed more than 5,000 ships for a total of over 11 million tons of shipping. In World War II, combat strategy once again depended upon vital oceanborne cargo from the United States. The annual volume in 1941 of 26 million

tons rose to 79 million tons of cargo in 1944. However, 733 American merchant ships were lost to enemy action.

In the Pacific, the Japanese Empire lost 4,861,000 tons of merchant shipping due to U.S. submarine action. The subsequent retraction of the overextended Japanese Empire proved the critical significance of control over the seas. At that time, incidentally, although ultimate capitulation was brought about by a dual American threat from the air as well from the sea, American planes were operating from overseas bases initially captured by naval supported forces and supplied mainly by surface shipping.

In fact, World War II dramatically proved the significance of seapower and with the revival of American naval strength after the critical losses at Pearl Harbor, the United States fought the war in the Pacific not only with conventional tactics, but also with striking innovations. Naval warfare became a multidimensional rather than a two-dimensional theater of operations; for the Navy, the air over the sea and the water beneath became closely integrated through sophisticated combat teams employing sophisticated techniques.

As a matter of national policy, the United States has resolved to maintain its supremacy in seapower.

On the contemporary scene, the Soviet Union, the chief antagonist of the United States in peace and potential adversary in war, controls a heartland position with a vast contiguous and monolithic land mass. In contrast, the free world is fragmented, scattered around the rim of the Eurasian continent and separated by large oceans and sea routes. The bivalent characteristics of the oceans give the free world distinct advantages so long as a dominant balance of seapower is maintained; but, if control of the sea declines while that of the Communist world is strengthened, the oceans then become the medium by which the free world may be divided. To underscore this point, in 1957 the total bulk transportation by ship was 250 billion ton-miles, which represents 99.5 percent of total tonnage moved by all means of transportation.

As a digression, statements of many national leaders may be recalled concerning the decline of the U.S. Merchant Marine. Only about 14 percent of our own foreign trade is carried in our ships. Projected construction plans do not promise to offset the obsolescence of the present merchant fleet of 1,035 ships, of which only 206 have been built during the last 15 years.[3] The most promising means for realizing a self-supporting U.S. Merchant Marine that can compete successfully in the world market has been said to lie in further mechanization, automation, and improvements in design and ship construction which, in turn, depend on research including oceanography.[4]

The roles, missions, responsibilities and prerogatives of the U.S. Navy in support of global commitments are clear. The Polaris program is a significant factor as a deterrent, but seapower has been at the very heart of our foreign policy with fleet elements deployed in the Mediterranean, the Middle East and the Far East. Adm. Arleigh Burke, before the Senate Armed Forces Committee, has noted:

> The U.S. Navy exists for two primary reasons. First, the Navy's task in cold war is to support the foreign policy of the United States in widely separated areas of the world. Second, the Navy's task in hot war is to control the use of the seas for U.S. purposes and deny their use to the enemy. In this role, the Navy must

[3] "An Introductory Survey of Some of the Considerations That Influence the U.S. Naval Shipbuilding Program," January 1960, by J. H. Probus, Committee on Undersea Warfare, NAS–NRC.
[4] "Project Walrus" Report of Maritime Research Advisory Committee, NAS-NRC.

control the sea approaches to the Western Hemisphere; supply and support the overseas operations of ground and air forces; maintain communications with friendly and allied nations around the world; and maintain communications with United States overseas sources of raw materials. * * * Every important decision we have made since the end of World War II is based on the fact that we can and will maintain control of the seas * * * seapower and world power are synonymous. * * * The Navy maintains two carrier striking forces deployed, and two in home water. * * * Our surface striking forces are capable of rendering surface and air defense support to our fleets * * * our submarine striking force has a primary mission of ASW but is also capable of attacking enemy surface forces. * * * Our amphibious striking force is capable of providing sea lift and * * * beach assault. * * * The Navy is particularly conscious of its ASW responsibilities. Our ASW capability is the sum of our ability in many fields. It depends on how well we are able to search for and detect submarines and finally to destroy them.[5]

In that regard, the Communist bloc is said to have 520 submarines while the United States has 196 and the fleet of the free world totals 384. Only 116 of the U.S. submarines are "in being"; the remainder are mothballed.[6]

As an insight into the problem which the United States faces, Carrison has noted:

The significance of the Soviet drive for seapower is manifested in many ways which are more subtle than the simple build-up of their submarine fleet * * *. The extent of sea support for Communist imperialism is shown by the following facts:

a. Since World War II the Soviet Union has constructed more combatant ships, with the exception of aircraft carriers, than any other nation in the world.

b. Sino-Soviet foreign trade is up 90% since 1953.

c. The substantial merchant shipbuilding program in each of these countries was highlighted in November 1958 by the Chinese announcement that they had constructed a freighter in the record time of fifty-eight days.

d. The Soviet oceanographic research program far surpasses that of the Free World.

e. Activities of the Soviet fishing fleets in both the Atlantic and the Pacific. Capabilities for other than routine fishing operations were verified by the boarding, in January, of the Soviet trawler in the vicinity of the Atlantic cable break.

f. The Soviet submarine forces in the Atlantic have become more venturesome and there are signs of more submarine activity in the Mediterranean.

g. A Soviet prototype nuclear-powered icebreaker has been constructed.[7]

The present situation has been further summarized by J. H. Probus: [8]

1. International Communism has the avowed goal of a Moscow-dominated, Communist controlled world. Communism will continue to use political, economic, psychological, military and covert elements of Soviet bloc power to achieve its aims.

We in turn are dedicated to the task of resisting world communization. We would like, ultimately, to see all people enjoy the freedoms we enjoy.

2. The prospects of unrestrained nuclear warfare are so horrendous that we must seek effective systems of deterrence. From a military and technological viewpoint, we have no choice but to confront the Soviets with the fact of their own assured destruction, should they initiate such a war. The Soviets are in a similar situation. The resulting capability for mutual destruction, so long as it is maintained under symmetrical psychological conditions, places severe limitations upon the usefulness of the threat of unrestrained warfare as an instrument of policy, except for acts of desperation.

3. There is no foreseeable possibility of our "breaking" the nuclear stalemate in the sense of obtaining absolute immunity to attack while preserving our ability to attack the Soviets. The record clearly indicates, moreover, that it

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[5] Senate Armed Services Posture Hearing testimony by Admiral Arleigh Burke, Jan. 26, 1959.

[6] "Jane's Fighting Ships," 1959–60 Edition and testimony by Admiral Burke before Senate Committee on Armed Services and Aeronautical and Space Sciences, Feb. 8, 1960.

[7] "The Soviet Drive for Sea Power," by Capt. D. J. Carrison, USN, U.S. Naval Inst. Proc., 85, pp. 67–71 (Oct. 1959).

[8] "An Introductory Survey of Some of the Considerations that Influence the U.S. Naval Shipbuilding Program," op. cit., pp. 16–17.

would not be greatly to our advantage to enjoy such immunity if in achieving it we denied to ourselves the possibility of conducting military actions on a lesser scale. It is essential to discourage the Soviets from launching a preemptive nuclear attack upon the United States. It is essential to seek conditions of stability that will reduce the risk of an accidental nuclear exchange, and that will enable us to preserve the existing nuclear stalemate—this while we simultaneously develop and maintain the capability to conduct military actions on a lesser scale for the purpose of giving our diplomacy greater freedom of action. And, of course, our total military expenditures must not be of such magnitude as to be self-defeating.

The problem is the BALANCING of our requirements and programs.

4. The United States is a key member of a free world oceanic confederation. We and the other members of this confederation are increasingly dependent upon the seas and upon surface shipping for our economic prosperity and our mutual security. There is no foreseeable alternative to surface ships for meeting our transoceanic transportation requirements—in peace or in war. We cannot now deter attacks on our surface shipping solely by threatening the use of land based weapons of mass destruction, nor could we before nuclear parity became a fact. When our distant ships are actually subjected to attack, we cannot effectively defend them from remote land bases. Our military capability *must* include sea-based weapons systems, not only to protect our surface shipping, but our own and friendly shores, and to allow us to project our military power abroad in the degree required to support our national policies, objectives and agreements.

Concerning the future, it is clear that every element of science and technology will be exploited by the Soviets in use of the sea to serve their national purpose.

The prudent course in developing plans and programs to meet an uncertain threat is to base these on unchanging or slowly changing principles and considerations, to maintain as much freedom of action as possible, to make rigid commitments in advance only when they are desirable, to avoid commitments when they are not desirable, and to seek wise balance of capabilities.[9]

Before concluding this section on historical perspective, mention should be made of research conducted by the United States on the sea itself, a tradition not widely appreciated. To be sure, much of this has had a romantic rather than scientific flavor. Nevertheless, it was Benjamin Franklin who investigated the nature of the Gulf Stream; 150 years ago, Nathaniel Bowditch of Salem, Mass., published "New American Practical Navigator," which became an international reference. Expeditions were sponsored by the United States in 1838–42, under the command of Charles Wilkes, concerning the South Pacific; in 1852–54, Perry explored Japan and 1853–59 expeditions studied the North Pacific.

The Coast and Geodetic Survey was founded in 1807, the predecessor of the Navy's Hydrographic Office in 1830. The systematic charting of tides, currents, ocean temperatures, bottom depths, winds and rainfall is credited to Matthew Fontaine Maury, who first published "The Physical Geography of the Sea" in 1855.

This phenomenal work of Maury's, however, was not subsequently expanded. In then withering, American oceanography failed to fulfill its early promise.

In 1927, a Committee on Oceanography formed under the National Academy of Sciences, took note of the serious neglect of oceanic research in the United States. Attention was effectively focused on the needs, following which substantial private sums were forthcoming for buildings and vessels, and generous endowments given institutions on both coasts. The momentum of nongovernmental

[9] "An Introductory Survey of Some of the Considerations that Influence the U.S. Naval Shipbuilding Program," op. cit., p. 19.

sponsorship did not continue indefinitely, and the situation which prevailed may be summarized as follows:

With the onset of World War II, practical applications of oceanography were recognized by the Armed Forces and funds became available for oceanographic work of all sorts. After the war, inflation made it impossible to continue oceanographic research on the pre-war scale without additional support. The Government has continued to provide this. Nevertheless the healthy growth of oceanography has been hampered by the uncertainty as to how long this support may be available, and by other restrictions.[10]

It was with this background of pessimism that a *second* study to review the needs of science of the oceans was initiated by the National Academy of Sciences in 1949. The results were published in 1951, summarizing research accomplishments and applications of oceanography in peace and war. Then current problems in developing oceanography were delineated with regard to ships, shore facilities, manpower and education and finances. Conclusions and recommendations are summarized in the following.

The Committee believes that the oceanographic sciences offer a rich and promising field for research. Continued progress is essential not only to increase man's understanding of the world in which he lives, and its biological processes, but also as a basis for the exploitation of the untapped resources of the oceans. To insure this progress both private and public support are needed to provide the stability and freedom prerequisite to basic scientific advances. Government support on a liberal and farsighted basis should continue to provide the extensive coordinated effort demanded by the size and complexity of oceanic phenomena.

The Committee recommends that a determined effort be made to secure *private* funds for the following specific purposes:

1. *Provision of research fellowships, at both pre- and post-doctoral levels, at existing oceanographic institutions.*—Such fellowships would enable young people trained in the basic sciences to use their abilities and experience on research in oceanography. Many of the recipients of such fellowships may be confidently expected to gain a permanent interest in and understanding of problems of the sea, and to make these problems a lifelong focus of their research work. Because of the specialization involved in oceanographic research and the time required to bring a research problem to a successful conclusion, these fellowships should be for at least two and preferably three years.

2. *Provision for visiting investigators both from American colleges and abroad.*—If it were possible to furnish adequate laboratory facilities and ships services to visitors at the existing laboratories, new ideas and advances in the basic sciences would quickly be applied to the ocean. Thus the isolation of these laboratories because of their location at the water's edge would in large part be overcome. Before this becomes feasible it will be necessary to alleviate the overcrowded conditions of laboratory buildings and to endow the unrestricted operations of the ships, at least in part.

3. *Provision of permanent positions for research workers in the oceanographic sciences.*—By far the greater part of oceanographic research is now supported by contract funds on a relatively short-term basis. As a result, commitments cannot be made for new positions with tenure at the oceanographic institutions despite the large increase in the numbers of persons engaged in oceanographic research. Consequently, considerable difficulty exists in attracting and holding research workers of the highest caliber. This situation should be remedied both by increasing the number of permanent staff positions at the oceanographic institutions and by providing faculty positions in universities.

4. *Provision for support of research in basic aspects of biological and chemical oceanography.*—These fields are not now receiving adequate support from government sources primarily because of their lack of immediate importance to military or fisheries problems. They present, however, many of the most challenging and promising problems of the sea.

5. *Support of high seas exploratory expeditions.*—The development of new methods for sounding and navigation, for geophysical and geological exploration of the sea bottom, for measuring currents and properties of ocean waters, and for col-

[10] "Oceanography, 1951," Report 208, NAS-NRC, p. vii.

lecting and studying marine organisms has proceeded very rapidly during the past ten years. Because of lack of funds these methods have so far been applied primarily to relatively nearshore waters. These new tools should be used for exploration of the entire oceans. With oceanographic ships and manpower presently available annual exploring expeditions of at least three months' duration could be carried out in both the Atlantic and the Pacific over the next five years, and would almost certainly yield results of importance in understanding the history of the Earth and the physical and biological processes in the sea.

To put these recommendations into effect the additional sums required annually are estimated, at present day costs, to be as follows:

To establish research fellowships	\$25, 000–\$50, 000
To establish staff and faculty positions	100, 000–150, 000
Unrestricted funds to operate ships	125, 000–150, 000
Basic research in biology and chemistry	200, 000–250, 000
Expeditions	50, 000–150, 000
Total	\$500, 000–\$750, 000

In addition, new laboratory construction will be required to replace temporary quarters now occupied at various laboratories.

These recommendations are based on the assumption that Federal and State support of oceanographic research will remain at the present level for the foreseeable future. Concerning Federal support the Committee recommends:

1. That present support of private oceanographic institutions be continued on as broad a basis and with as much continuity as possible.

2. That agencies of the Federal Government conducting oceanographic work should increase the amount of effort devoted to basic research and to long-term scientific objectives in addition to carrying out ocean surveys and work of immediate practical application.

3. That oceanographers employed in the Federal Government under Civil Service should be assigned to work from time to time at one of the major oceanographic institutions. By actual participation in research on the frontiers of oceanography their insight would be quickened and their interest refreshed. At the same time, their colleagues on the staffs of the oceanographic institutions would gain by contact with practical problems which are of primary concern to the Government agencies.

4. That through the United Nations and the Point Four program the United States should encourage the rebuilding and development of oceanographic research centers in other countries, particularly in the southern hemisphere and the western Pacific. Because of the unity of the oceans, the interests of the United States would be well served by developing oceanographic centers in other countries which could cooperate with our own oceanographic agencies in coordinated exploratory programs.

If funds become available for fellowships and for expeditions, these might appropriately be administered by the National Academy of Sciences, the National Research Council, or the National Science Foundation. In addition it would appear desirable that continuing surveys be made from time to time of the progress of the oceanographic sciences, and these could be carried out by this Committee.

The Committee recommends that it be continued for this purpose.[11]

Suffice it to say that this 1951 set of recommendations failed to develop adequate response for, late in 1957, the National Academy of Sciences was called upon a *third* time, now by a number of Government agencies, to form a new Committee on Oceanography and once more to take stock of United States needs, and level of activity, and to formulate a long-range program for the future.

The 1957 study (NASCO reports) developed background information in authoritative detail and called for an expanded program in clear and forceful language. It received much favorable publicity. As is noted subsequently, this study has been a primary stimulus to interest by the Congress. The substance of the NAS surveys of present effort and of proposals for a 10-year long-range program has been analyzed in Sections VI and VIII of this current report.

[11] Oceanography 1951, Report of the Committee on Oceanography of the National Academy of Sciences, op. cit., pp. 27–28.

B. THE RECENT SENSE OF URGENCY FOR OCEANIC RESEARCH

1. Implications for Defense

Why now a sudden renaissance of interest in the sea?

The most urgent and compelling reason generally cited is that of self-preservation. In terms of military strategy, the continental United States has been considered an island. Surrounded on essentially three sides by water, and with friendly nations at our land boundaries, the relationship of the United States to other nations, hostile or friendly, has historically been that of an island power.[12] In freeing the United States from threats of invasion, the sea provided a protective barrier that offered the most elementary and inexpensive type of defense.

The United States is itself committed to an underwater weapons system as part of our cold-war policy of deterrence in which the Polaris submarine represents a mobile, concealed base for the launching of intermediate range ballistic missiles. It is perhaps ironic that the United States is itself vulnerable to the same strategy.

Now, for the first time since 1812, strategists see a critical threat to our national survival coming from the sea. Our coastline is long and exposed; many of our major cities are directly on the coast, but missiles launched far off shore in international waters can easily reach St. Louis, Denver, Chicago, Albuquerque. The numerical strength of the Soviet submarine fleet is common public knowledge—from numerous sources, said to number between 400 and 500 relatively new boats. Although by no means equal to Polaris subs in nuclear-tipped missile capabilities, many, if not most, could surface-launch some type of IRBM. None of these is believed yet to have the advantage of nuclear power, with its potential for sustained submergence, or enhanced submerged speed. But what may be a deficiency in high speed and submerged performance can be more than offset by their overwhelming numbers. Conceivably, by extremely quiet operation that would permit their stealthy approach to our shores, they could reach "station" possibly undetected, or even if detected, in sufficient numbers to saturate our anti-submarine defenses.

Does this capability give the aggressor an unbalanced advantage? In the first instance, emanating from the element of surprise, the aggressor always has some advantage. That fact is not a specific characteristic of undersea warfare, but the oceans can effectively hide activities within their depths. The presence of submarines is almost exclusively detected by use of acoustical techniques—either a passive system of listening for the vehicles' self-noise, or an active system of steady pinging, listening for the echo. Neither system has great range. Both are highly dependent on details of the ocean medium. Thus underwater surveillance becomes a nightmare as compared to the use of radar which can patrol great distances and volumes of sky.

The history of warfare is filled with examples of new and potent weapons initially hatched with demonstrated characteristics of surprise, of speed, of mobility, of invulnerability to counterattack. Usually this technological superiority in warfare is only temporary—at least if countermeasures are vigorously pursued. Where the need

[12] Yet, next to Mexico and Canada, Soviet Russia is our nearest neighbor—only 58 miles across the Bering Strait from the 49th State, Alaska.

is urgent, technology has always produced a defense against the promise of the new offense, and the submarine menace can hardly be expected to be immune from an analogous development.

The problem lies within the sea—and students of the problem say that the solution must be sought within the sea. More sensitive listening equipment even now is known to pick up the sounds of underwater life, such as the clicks of shrimp, the grunts of certain fish, the groans and moans of unknown sources, the background noises of the surface waves, the reflections from underwater mounds and bottom irregularities. But in the interleaving layers of warm water and cold, in the upwelling of currents, underwater sounds are reflected and refracted such that grave difficulty exists in establishing a high degree of reliability in detecting unwanted underwater objects. Antisubmarine units frequently chase "ghosts."

Herein lies the core of the ASW problem—study of the medium itself, on the basis of which a strong defense could be erected against the surprise of underwater missile launching subs.

The necessity of an enhanced undersea defense has thus been cited as the primary stimulus for an accelerated program of oceanographic study, a point of view supported by a number of the Members of Congress as the following excerpts of but a few similar speeches show:

Senator Hubert H. Humphrey (Minnesota), in a statement on "Importance of Studies in Oceanography," *Congressional Record*, February 17, 1959, pages 2279–2280 noted:

* * * * * * *

About a year ago, Dr. Brown discussed with me for the first time the state of our Nation's knowledge of the oceans surrounding us, and the fact that the scientists of the Soviet Union were hard at work not only in rockets and missiles, but in oceanography—the study of the oceans and of the life within them.

I was powerfully reminded that we of the West—the Atlantic Community, the nations whose common physical bond is the Atlantic shoreline—have, in still another major lapse of attention, very nearly permitted ourselves to be left in the wake of another surge of Soviet scientific advance. I came to realize how pitifully inadequate was our knowledge of the seas which traditionally have been the lifelines of the Western World—over which far more than nine-tenths of all our men and material moved during World War II, and over which our forces flowed to Korea and to the later trouble spots of the world that required the presence of American armed forces.

I came to realize that the ocean deeps and the offshore shelves of the continents would ever increasingly become the arena in which the fateful decisions of war might very well be fought.

The intense concentration of the Soviet Union on submarine development and construction—to a degree surpassing by five times the prewar effort of Nazi Germany—began to be seen in its proper perspective. Soviet effort on submarine building, Soviet progress in missile development, totaled a program of awesome dimensions for the offensive use of the ocean spaces.

Mr. President, let me add that the Soviet Union seeks to make the ocean its great base of operations—a base which covers three-fifths of the Earth's surface.

* * * * * * *

Among the two great gaps, then, in our national armor is the failure to maintain even a fraction of the modernized, mobile, but conventional forces needed to deter Communist conventional probings and attacks.

The second great gap is related both to the problem of dealing with conventional or limited war and to that of preserving a true deterrent against massive strategic attack on the United States. This is the gap caused by our ignorance of the secrets of the oceans, the marked failure of the antisubmarine science to keep up with the progress being made by the world's submariners, and the all-out construction program of the Soviet undersea force.

The Soviet submarine threat to the vital sea supply lanes of the Western World, coupled with the probability—as the Chief of Naval Operations indicated recently to my subcommittee—that the Soviet Union now has missile-carrying submarines,

constitute reason enough for us to take serious alarm at the state of our sea defenses. This threat is reason enough, in itself, for us to be grateful for the monumental service which Dr. Harrison Brown and his distinguished colleagues on the Committee on Oceanography are rendering their Nation in focusing attention on the low state of the oceanographic art in the West, and in proposing hard, concrete, specific measures by which we can regain the lost initiative in this critically important field of knowledge.

* * * * * * *

Representative Hastings Keith (Massachusetts), concerned that the "United States Is Losing to Russia in Vital Race To Harness Oceans," entered the following statement in the *Congressional Record*, March 9, 1959, page A1950:

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The ocean not only covers approximately three-fifths of the Earth's surface—it could hold the key to the future of humanity. And we in Congress have it within our power to see that the United States is first to unlock the mysteries of the seas, and with this knowledge to work for the betterment of mankind everywhere.

The Soviet Union will be the victor in this vitally essential area of science—and military or economic defeat of the United States could result—if our country fails to regain the margin of leadership it once held in oceanographic research.

Startling and sobering in its revelations is a series of articles by Everett S. Allen, staff writer of the New Bedford (Mass.) Standard-Times. The articles were published in that newspaper last year. The urgency of their appeal for an awakening on the part of this Nation to the need for an expanded program of ocean study is heightened with the passing of time. Nearly 1 year has elapsed since Mr. Allen's reportorial voice was raised, and the opening statement of his first of 13 articles rings as ominously today as it did when first printed:

The United States is losing to the Soviet Union the biggest and most important sea battle in mankind's history—the contest to unlock the ocean's secrets for use in peace or war. Principally by default, American oceanography is surrendering the lead in a half dozen marine science fields to a Russia that is better equipped, spending more money, and able to put more capable scientists on this particular assignment.

And what of the role of Congress? Only Congress has the authority to provide the tools and manpower that are needed if this Nation is to win this most important race—a race we cannot afford to lose. And with that authority goes the responsibility for restoring the United States to its once favorable position in this field.

Experts have estimated that the present level of financial support for the marine sciences is approximately one-fourth of what is needed if this country is to prevent the Soviet Union from overtaking and surpassing the United States.

To compare the amount of money spent on sea research with that spent on space research is not to minimize the need for the latter. But a comparison of the importance of these two areas of study would indicate a disproportionate percentage of funds going into space research. It is the conviction of sea scientists that returns from the investment of additional money in oceanography would more than justify such expenditure. Now that the United States has drawn alongside the Soviets in the race for outer space, it is essential that we concentrate as well on developing to the fullest our capacity for probing the oceans.

And it is as an investment that funds for oceanography should be regarded. With our very freedom, economic and otherwise, at stake, there remains no alternative course of action. We must step up our oceanography program.

* * * * * * *

Sea Battle, 1958: Key to Survival, I—United States is Losing to Russia in Vital Race To Harness Oceans

(By Everett S. Allen)

The United States is losing to the Soviet Union the biggest and most important sea battle in mankind's history—the contest to unlock the ocean's secrets for use in peace or war. Principally by default, American oceanography is surrendering the lead in a half dozen marine science fields to a Russia that is better equipped, spending more money and able to put many more capable scientists on this particular assignment.

Further, since Russia is largely a landbound country, it has been suggested her primary interest in the sea might well be for aggressive purposes.

It is noteworthy in this respect that the Soviet Union's chief target in either a hot or cold war, the United States, has the largest coastline of any nation in the world.

Reds Gain Rapidly

Soviet oceanography 10 years ago was provincial. Today, it is worldwide in scope and progressing rapidly. Russia has initiated a crash program in ocean study comparable to the rocket-outer space effort that produced Sputnik.

For it is increasingly accepted in scientific circles that whoever controls the seas and whoever knows most about them—not only from coast to coast, but from top to bottom, as well—could conceivably control the world, the effect of airpower notwithstanding.

These are the concerted views of America's leading oceanographers, qualitatively among the world's best, who have been interviewed exclusively by the Standard-Times to find out how the United States stands in a scientific race on which the world's survival could rest. For the future depends upon the sea, which covers three-fourths of the Earth's surface, and contains the answers to most of its pressing problems.

By comparison, they say, rocketry, missiles, space transport, and the like are essentially adventures in gadgetry. That is why most oceanographers, seriously concerned at the prospect of Russia establishing a long lead in the Earth sciences, warn:

"Spend all of America's might and money on rockets, and you will still lose the war with Russia, whether it be cold or hot."

Seas To Be Decisive

To the degree to which the Soviets gain a lead in oceanography, the possibility of war increases. If there is war, there is sound reason to believe the seas—not the air or outer space—will be the decisive theater of military operations.

As weapon systems evolve the submarine-launched missile will prove to be the most effective, for it will be extremely difficult to tell where it came from, and it can be launched close to the target, allowing little time for defense tactics. By contrast, the intercontinental ballistic missile will allow defenders several thousand miles worth of reaction time before it arrives in the target area.

The ocean also is the medium over which America must carry supplies and support to its allies if the free world is to stand. Further, in the modern concept of atomic war, the seas' depths are the most effective hiding place for concealing both offensive and defensive action.

If there is cold war only, there still remains the present struggle for balance of power in the world. Of tantamount importance in this East-West contest for alliances are the underdeveloped "have not" nations, which require such basics as food and fuel. Also torn between necessities and loyalties are many of the more developed countries, which are in pressing need of cheap power and new sources of minerals and metals when petering-out mines are exhausted.

Ocean Holds Keys

In the ocean lies the answer to all of these things, fundamentally important in peace, critical in war. Either Russia or the United States will find the keys to these secrets, since no other nation is making anything like the deepwater scientific effort of these two—and the Soviet effort is several times that of America.

The nation that does score an eventual breakthrough on any of these principal marine fronts will be in a greatly enhanced position, through prestige, politics, and persuasion, to tip the worldwide balance of power.

As an example, which way would India's hungry millions look for leadership, East or West, if Russia first found a practical means of providing limitless quantities of fish protein for 1½ cents a pound or less to Nehru's money-poor country? Protein is a principal lack of the Indian diet, and this question will be answered one day.

A statement by Senator Warren G. Magnuson on "Critical Lag in Oceanographic Research," was placed in the *Congressional Record*, June 1, 1959, page A4591 by Senator A. S. Mike Monroney (Oklahoma):

* * * * * * *

Soviet Russia is winning the struggle for the oceans.

Scientists call it the wet war, and say the outcome can determine the fate of nations and the human race.

Without firing a missile, a rocket or a gun, Soviet Russia has been winning in the Atlantic, the Pacific and the Antarctic. This year she is invading the Indian Ocean.

Had it not been for the stubborn persistence of wiry little Adm. Hyman Rickover, father of the atomic submarine, Russia also would be winning in the Arctic, where she has bases 2,200 miles from Seattle and within 3,550 miles of Detroit and Chicago.

Russia has been winning the wet war with more and bigger ships; more, if not better, scientists; more, and in some instances superior, equipment, and more aggressive government encouragement and action.

The United States cannot permit Russia to achieve a global conquest that would give her control of 95 percent of the Earth's surface. We must meet Russia's challenge. We can meet it without sacrificing a drop of American blood if we start now, but if we wait for tomorrow it may be too late.

Soviet Russia has between 450 and 500 submarines and a capacity to build 100 more each year; the United States has 109.

Soviet Russia has 29 icebreakers, the world's biggest and heaviest, and is building more including an atomic icebreaker almost completed. The United States has eight.

Soviet Russia has the world's largest oceanographic research fleet with four times as many ships capable of deep sea work than we have. Her ships are modern, new; ours old and obsolete.

The Soviet is conducting intensive offshore explorations for oil beneath its continental shelves, and minerals research in all oceans. Three hundred miles off Lower California Soviet scientists have taken sharp deep-sea photographs of the mysterious manganese-cobalt-nickel-copper nodules which thickly carpet the ocean floor in that and some other oceanic areas.

Reds Lead World in Oceanic Studies

Russia has more ships and scientists in the polar regions than all other countries combined.

Russia has more ships and scientists assigned to deep ocean studies than any other nation. She has 800 professional oceanographers compared to the 520 in the United States.

Soviet Russia aspires to command the oceans and has mapped a shrewdly conceived plan, using science as a weapon, to win her that supremacy.

Should she be successful she would control commerce, weather, communications, much of the world's food supply, and ultimately Earth's resources, health and climate. The human race, if it survived, would be in permanent bondage to Soviet masters.

"Soviet effort in oceanography is massive, of a high caliber, and is designed to establish and demonstrate world leadership," states Vice Adm. John T. Hayward, Assistant Chief of Naval Operations for Research and Development.

The wet war Russia is waging may be more dangerous to free world security than her space war or her polar war.

* * * * * * *

Parallel sentiments were expressed recently by Dr. Harrison S. Brown, Chairman of the NAS Committee on Oceanography, before the House Science and Astronautics Committee:

Our major conclusion was that relative to other areas of scientific endeavor, progress in the marine sciences in the United States has been slow.

I would like to discuss this area by area, if I may. Now, first I would like to discuss the problems of defense in relation to the marine sciences.

When we look at the evolution of modern weapons systems, it is amply clear that one of the major problems which confronts us is that of creating hardness in our missile bases.

This is a very real problem on land. Coupled with this, we are faced with the brute fact that no matter how hard we might make a missile base on land, it is difficult to create it in such a way that people in neighboring communities are not going to be killed should there by an enemy attack.

I personally have thought a great deal about these problems, and again and again I am forced to the conclusion that we are being pushed into the oceans as a major answer to this problem.

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I believe that in another decade or so warfare is going to be conducted primarily in the oceans.

I believe that the emergence of the Polaris submarine is a strong indication that we have already gone a long way down this path.

Now, if we are going to fight a war in the oceans, it means we have to know something about the oceans.

The victor, in such a war, will be that nation which knows most about the oceans.

An analogy which members of my committee have used is that in the old days of the Indian wars the Indians often achieved victory over the whites, not because they were superior in strength, but rather because they knew how to handle themselves in the forests and in the woods.

Similarly, in the oceans, we must learn how to handle ourselves. and it is for this reason that essentially anything that we learn about how to maneuver in the oceans, how to find things in the oceans, will help us should we be forced to fight such a war.

Now, the problems of offense in the age of undersea warfare are difficult.

We have long-range nuclear submarines, but these submarines have to find out where they are under the water.

Now, how are they going to find out where they are under the water?

Well, one way is to recognize certain geographic objects such as mountains or valleys.

If they cannot find where they are under the water, then they have to surface, and then they are in danger of being found.

Similarly, how are they going to find out where they are without emitting radiation?

It is very difficult to communicate without giving out some kind of a signal or receiving some kind of a signal, and if you give out some kind of a signal then enemies as well as friends can find you.

So the problem of self-protection in relation to communications is extraordinarily difficult.

These problems really will only be answered as we learn more and more about the properties of water—sea water—and the properties of the life forms which exist within the sea.

Let us take the analogous problems of defense.

Today we find submarines using what is known as sonar. Here we take sound waves and shoot them down and they are reflected off of objects.

The whole problem of the behavior of sound waves in sea water is a very complex one. For example, arrays of living organisms will give off background sound or noise. This has to be interpreted.

Aggregates of living organisms can confuse and attenuate acoustic signals which we ourselves send out.

All of these things make the problem of using sound waves for detection purposes, or for that matter for communication purposes, extremely difficult. And indeed, I believe myself that the long-range nuclear-powered submarine capable of carrying long-range missiles is in the long run the most serious military threat that the United States faces. And learning how to find such submarines is perhaps the most serious and difficult technical problem which we face today in the military field.

I don't believe that this problem is going to be solved really until we learn a lot more about the oceans than we now know.

If I might move to another area of defense, it involves the handling of submarines and it involves the handling of surface ships.[13]

2. *Implications Concerning Scientific and Economic Development*

The general problem of studying the sea is intensified because of its expanse. Water covers roughly 71 percent of the surface of the Earth, a feature well known to every observer of a globe; the area is immediately visible; the identity of the shoreline is well defined. But this is just a two-dimensional portrayal of the oceans; the third dimension—that of depth—is seemingly neglected. The sea averages about 13,000 feet in depth. The deepest point is roughly 35,800 feet; 80 percent is deeper than 9,000 feet. The oceans contain 1.5 billion billion tons of water; if the surface of the Earth were bulldozed

[13] "Frontiers in Oceanic Research," Hearings before House Committee on Science and Astronautics, Apr. 28–29, 1960, pp. 5–6.

smooth, sea water would cover it to a depth of 12,000 feet. Truly, the Earth is the "water planet" for no other planet retains its moisture in liquid form. And it is this part of the planet that is largely unknown.

Man's activities on the planet have always included exploration. By restless curiosity alone, but more likely in search of the miracle of fabulous discovery, man has rather thoroughly unclothed the continents. To be sure, detail is scanty about certain parts, whether in terms of topography, or more particularly subsurface mineral content, but about the ocean floor, man knows next to nothing. The resources of the ocean thus remain untapped.

The need for these resources, whether mineral or biological for human nourishment, is often considered a problem of the next generation—so that the urgency for immediate exploitation may superficially appear marginal. But any statement of the economic "payoff" of such research is academic since little is known of what is there in the first place. The order of priority would first call for charts of the oceans in terms of their physical description of temperature, salinity, the presence of currents, etc.; then of the ocean floor in terms of topography and mineral content; collaterally more knowledge is needed of fish populations. Even without the urgency of a hunt for such materials today, it is argued that basic research and surveys will lay the groundwork for such efforts of tomorrow, and it may well be in the future self-interest of the United States that it be among the first and not among the last to know what to expect. Many legal problems associated with the 3-, 6-, or 12-mile continental limits and with mineral claims on the bottom of the high seas remain unsettled. Also remaining are the potential of piracy and of means for protecting such claims. Questions of national sovereignty raised by the appearance of alien satellites overhead are at least being examined if not solved—and there appears to be a trend to consider outer space a new medium that is free of the national rivalries and competitions, tensions, and threats that have characterized terrestrial holdings. "Freedom of the Seas" has been a concept that has been relatively easy to enforce so that a purely philosophical and idealistic concept was consistent with practical reality. But in the day of "bottom crawlers," perhaps two competing nations equally interested in mining a supply of manganese nodules in 12,000 feet of water, 500 miles from the nearest land, will come armed with the counterpart of weapons of the gold prospector. The 1958 Geneva Convention on "Law of the Sea" set ground rules for mineral rights that are yet untested. Being there first carries an impact all its own.

By itself, exploration is regarded by oceanographers only as a first step; actually both exploration and research have been stressed. Scientific research, it should be recalled, is the development of new knowledge that can be fitted into the cumulative store of past observations so as to lead to a better understanding of the world around us. While exploration may answer the questions of "what?", research through application of the scientific methods permits generalization into broader "laws of nature" that may answer questions of "how?". *Understanding* is the first step toward *prediction* of phenomena, and ultimately toward *control*.

For instance, the implications of science in regard to weather have gained much recent publicity—the hope has frequently been expressed that by further study, man may eventually control or at least modify

it. Control of climate, however, is both more significant economically, and more possible, technologically, for climate involves much longer range processes than the transients of weather that may be triggered from purely local atmospheric instabilities.

The influence of the sea on terrestrial climate, the manner in which the oceans or currents such as the Gulf Stream modulate the climate of contiguous land masses is familiar to all.

The first step, however, is not in control of ocean currents by building dikes to divert them, but research to understand what they are doing and to predict what will happen so we can, in turn, see how this affects the climate and the weather. Our ability to forecast climate is nil. We have no idea what the climate will be like on Earth 50 or 100 years from now, or even 10. In the system of heat energy coming into the Earth from the Sun and affecting the atmosphere and oceans, the ocean is the great flywheel that significantly influences climate, and it is only by understanding the oceans that we can hope to predict climate as opposed to the prediction of weather a few weeks in advance.

To be more specific, the most important contribution of the oceans is their being the source of rainfall. Virtually all of the moisture formed in clouds originates through evaporation from the oceans. This moisture returns to the Earth in the form of precipitation, either by rain or snow. That falling on land eventually finds its way back to the oceans, carrying with it the granular material eroded by mechanical action of the rain and winds, by the scouring action of running water, the wedging action of water expanding when freezing. These sediments may later form continents. The accurate prediction of annual rainfall would be a first target of the application of ocean sciences to eventual climate control.

Man has suffered the extremes of climate; the places he has chosen to live have been severely influenced by many random factors of convenience, transportation, proximity to essentials, and subtle influences of commerce, etc., but not the least factor in selection has been climate. Often other factors predominate and man puts up with inconvenience and discomfort because of the other benefits—but he would like to control the extremes of temperature, and to control any natural phenomenon requires some understanding of the phenomenon. The salutary economic implications for the climatically less attractive regions of the world, particularly in an era of burgeoning population, are obvious.

Still other implications for economic development are discussed in the succeeding chapter, particularly concerning improvement in fisheries, in sea transportation and in scientific knowledge generally. The essence of this dual potential for oceanic research was summarized by Assistant Secretary of the Navy, Dr. James H. Wakelin, Jr.:

> It has been said that, like the subject "Atoms for Peace," we can use the oceans for peace. We must have leadership on the oceans in the face of the threat of war and equally we must have leadership on the oceans in our hopes and our work toward peace.[14]

[14] "Frontiers in Oceanic Research," op. cit., p. 49.

C. ROLE OF THE FEDERAL GOVERNMENT

In light of the prior discussions, the relationship of the sea to national security becomes more evident, and in this context, a number of Congressional leaders have stressed the role of the Federal Government in fostering research in the sea.

This point of view was succinctly developed by Senator Warren G. Magnuson in an address before the Franklin Institute, February 17, 1960, sections of which follow: [15]

> Modern naval warfare, so much of it conducted beneath the surface of the oceans, requires broad knowledge of bottom topography, sound velocities, subsurface temperatures and currents, biological activity, nuclear components, ambient noise and ocean sediments.
>
> Even now the Navy admits a significant lack of this knowledge in the North Pacific, the Northeast Atlantic, the Pacific Ocean, and many other areas.
>
> The chemistry of the oceans must be known at varying depths and samples taken for nitrates, oxygen, salinities, and phosphates. We should learn much more than we know now about the magnetism and gravities in the ocean, about wave motion, and about the mineral treasures of the sea.
>
> Congress, recognizing the increasing role of science in national defense, in 1946 created an Office of Naval Research. ONR was given authority to conduct research and development work both in Government facilities and through contracts with individuals and educational and scientific institutions. The latter grant was based on the premise referred to earlier in my remarks that basic research, as distinguished from applied, could best be done in an academic environment.
>
> ONR also was directed by Congress to promote and encourage initiation, planning, and coordination of naval research, and given authority to make ships available to oceanographic institutions, or to assist in financing operations of the research ships these institutions already had, and would make use of in contract programs.
>
> These research contracts were and are from year to year and dependent on allocations from the annual naval budget. Demands for naval hardware and fleet operations are such that ONR almost invariably finds itself pushed to the foot of the lineup at the budget table.
>
> Science suffers, all marine sciences suffer, under this procedure. A comprehensive, long-range program of oceanographic research and surveys, approved by Congress and directed by statute, is necessary to correct it.
>
> * * * * * * *
>
> * * * So I shall talk about the role of the Federal Government in this field—what it is doing in marine research, what many of us in the U.S. Senate think it should be doing, why we think the way we do, and what we are proposing Congress do to assure expansion of the marine sciences.
>
> First, let us consider what business the Government may have in the field of scientific research, particularly basic scientific research. All of us agree that maximum scientific achievement requires great scientific freedom and a minimum of Government direction and control.
>
> I recall that the question of Government involvement in basic research was raised when, in 1937, I introduced the bill to establish a National Cancer Institute, the first legislation of this kind to be enacted by the Federal Government. Today we have seven National Institutes of Health, all doing splendid work in medical research. The question of Government participation in research designed to alleviate the afflictions that beset mankind appears to have been resolved.
>
> The question again was raised when, in 1945, I introduced the first bill to create a National Science Foundation. This bill authorized and directed the Foundation to encourage and support basic research and education in the sciences. The Government had never entered the field of basic research before. Dr. Vannevar Bush worked with me on this legislation and assisted in its drafting. It required 5 years to convince Congress and the administration that we needed a National Science Foundation, but we finally succeeded. Today, although the agency certainly has proved its value and is being continually expanded, there are some people who question the Government's support of basic research.

[15] *Congressional Record*, March 23, 1960, pp. 5883–5885.

Research that has immediate and demonstrable application appears easier to advocate successfully than does research that promises general gains at some undetermined time in the future. Yet we know there must be a foundation of basic scientific knowledge before we can anticipate effective application.

Why must the Federal Government invest in science?

One reason is that we are living in a scientific age. Our security, health, welfare, economy—perhaps our very survival as a free nation—depends on keeping abreast in science with the other great powers.

A second reason is that national benefits accrue from expanded scientific research far outweighing the costs, and where there is a national benefit I feel there is a national duty to support such research.

A third reason is that scientific research in many fields is today too costly for most private or State institutions and laboratories to undertake to the extent the demands and tensions of these times require without the assistance of the Federal Government.

Government grants to these laboratories and institutions assure that the required research will be done where effective results can best be accomplished.

*   *   *   *   *   *   *

* * * In my opinion our lag in marine research can be as fatal to our welfare and security as failure to match Russia in space research and development.

When the Committee on Aeronautical and Space Sciences was set up I rather hoped that it would consider the scientific problems of inner space—represented by the oceans and the earth beneath them—as well as those of outer space, and I regret that it has not done so.

Sonar and related systems will enable submarine officers to hear better and in effect to see farther than their counterparts on surface vessels. Cavitation is reduced in undersea operation and some marine scientists dream of a day when it may be eliminated entirely, as nature has done with the dolphin.

Commercial undersea navigation will require all the scientific knowledge and aids that naval undersea craft need today. The Russians are making aggressive efforts to supply this knowledge to their own subsurface mariners. One of their objectives is, of course, year-round navigation of the Northern Sea route.

Russia has another important objective for ocean research, to increase her deep sea fisheries catch. Russians, with their cold climate, have an urgent need for high protein foods, and her meat supply is deficient and probably will remain so. To offset this deficiency Russia has turned to the sea.

Today Russia is operating the largest and most efficient fishing vessels afloat. Some of her huge floating combines, as they are called, will take as many fish in one trawl as our ships will catch in a month. Russia is operating fishing fleets off the Grand Banks of Newfoundland and along the coast of Alaska, and has fisheries also in the Central Pacific, the mid-Atlantic, and along the African coast.

Russia's fisheries research fleet is the finest and largest in history and includes at least one submarine. All of her major fishing vessels carry the latest scientific equipment for locating rich fisheries and scientists to operate this equipment, so these ships supplement her research fleets.

Our own fisheries are dwindling; our fisheries research is degressing, and our fisheries catch is dropping every year. Our research fleet, always small and always limited to coastal waters, has declined in quality and numbers, and the Bureau of Commercial Fisheries cannot even operate all the ships it has because of lack of funds.

What are we doing about the Russian challenge, or complex of challenges, for mastery of the oceans?

*   *   *   *   *   *   *

* * * Members of the Committee on Interstate and Foreign Commerce studied these reports and were intrigued with them. On June 22 I introduced a Senate resolution endorsing these reports and recommending that the basic recommendations be adopted. All members of the Senate Commerce Committee joined in cosponsoring this resolution, including the junior Senator from Pennsylvania. It was cosponsored also by my colleague, Senator Jackson of Washington, a member of the Armed Services Committee and the Joint Committee on Atomic Energy. The resolution was reported unanimously to the Senate by the committee on July 13, and on July 15 the Senate adopted it without a single dissenting voice.

This resolution outlined what should be done, but did not provide legislative authorization or direction. For that reason it was necessary to draft a bill which was done with the advice and counsel of oceanography committee representatives.

This bill, cosponsored by myself and 13 other Senators, including both Senators from Pennsylvania, was introduced on the final day of the 1959 session in order

to give scientists and educators throughout the Nation an opportunity to study it during the congressional recess and to present their views. As a result the committee has received many fine comments from many scientists.

The Federal agencies to which the bill was sent also for comment, have not been equally responsive, and some Government officials, it is reported to me, have taken the view that no legislation is needed at all.

In this connection I will refer to a letter from the Chief of Naval Operations, written to me on June 16, 1959, in which he said in part, and I quote:

"The interest of the Congress in this vital area is timely since legislative assistance will be required if all the recommendations of the Harrison Brown committee are to be implemented for a sustained 10-year effort."

The resolution referred to previously, reflecting the importance which the Senate attributed to the problem of oceanic research, follows:

86th Congress, 1st Session — S. RES. 136

IN THE SENATE OF THE UNITED STATES

June 22, 1959

Mr. Magnuson (for himself, Mr. Engle, and Mr. Jackson) submitted the following resolution; which was referred to the Committee on Interstate and Foreign Commerce

RESOLUTION

Whereas expanded studies of the oceans and the ocean bottoms at all depths are vital to defense against enemy submarines, to the operation of our own submarines with maximum efficiency, to the rehabilitation of our commercial fisheries and utilization of other present or potential ocean resources, to facilitating commerce and navigation, and to expand our scientific knowledge of the waters covering 71 per centum of the Earth's surface, life within these waters, and phenomena which effects climate and weather; and

Whereas several other nations, particularly the Union of Soviet Socialist Republics, are presently conducting oceanic studies of unprecedented magnitude on a worldwide basis, utilizing larger, more numerous, and more modern ships and more scientific and supporting personnel than ever before; and

Whereas a Committee on Oceanography, comprised of eminent scientists from universities and nongovernmental institutions, appointed by the National Academy of Sciences-National Research Council, has prepared a report outlining objectives and recommending a comprehensive program of oceanographic research to be carried out at nominal cost over a period of ten years; and

Whereas the Office of Naval Research of the Department of the Navy, observing that there has been no effort to improve the Nation's research fleet in the past fifteen years, and that there is need for more oceanographic scientists, laboratories, specially designed ship and shore facilities, has prepared a report recommending a ten-year, long-range program for oceanographic research which has been approved by the Chief of Naval Operations; and

Whereas the Coast and Geodetic Survey of the Department of Commerce, directed by statute to conduct hydrographic surveys, seismological investigations, magnetic and gravimetric observations, and other scientific operations, but restricted generally to coastal waters and limited in its work in these waters by obsolescence of its research ships, has drawn up plans to rehabilitate its scientific vessels and broaden the area in which it can operate, subject to departmental and Bureau of the Budget approval; and

Whereas the Bureau of Commercial Fisheries of the Fish and Wildlife Service of the Department of the Interior, faced with a drastic diminution of a valuable food supply and resource and an actual decline of ships and facilities for fisheries exploration and research at a time when Soviet Russia, Communist China, Japan, and many other nations are expanding fisheries research intensively, has a plan, which still waits departmental and budget approval, to replace its present small and overage vessels over a ten-year period: Now, therefore, be it

Resolved, That the Senate—

(1) commends the report of the Committee on Oceanography to the President, the Bureau of the Budget, and to the heads of the five departments and nine agencies which would participate in the ten-year program of oceanographic research recommended by the Committee, for their study and

consideration with a view to overcoming this Nation's lag in this scientific field, and urges their support of a comprehensive plan that will assure the United States permanent leadership in oceanographic research;

(2) commends the programs of the several agencies for rehabilitating their research facilities and enlarging their oceanographic activities to the President and the Bureau of the Budget for like study and consideration with the object of developing a well-balanced and coordinated expansion of scientific effort in this vital field;

(3) concurs in the recommendations of the Committee on Oceanography that—

(a) basic oceanographic research be immediately expanded and at least doubled within the next ten years;

(b) in the field of applied research fisheries exploration be intensified, migratory patterns investigated, greater attention given to genetics of fish and other marine organisms, biological surveys augmented utilizing new devices, a program on diseases and other toxic effects in the marine environment established, comprehensive studies made of the economic and legal aspects of commercial fisheries, especially in relation to other industries, and research stimulated on the nature of organisms in the sea on which marine life of commercial or sports value feeds;

(c) training of more oceanographic scientists in private educational and research institutions be encouraged and facilitated by the National Science Foundation and the Office of Education with the object of doubling the number of oceanographers at the doctor of philosophy level during the next ten years;

(d) systematic ocean-wide and ocean-deep surveys be conducted by the Coast and Geodetic Survey and Hydrographic Office, Bureau of Navigation, Department of the Navy, to develop much broader knowledge of depths, salinity, temperature, current velocity, wave motion, magnetism and biological activity;

(e) research fleets of the various agencies and institutions engaged in basic or applied oceanographic research, of which most of the vessels are old and obsolete, be replaced by modern ships adapted to ocean-wide scientific studies and furnished with advanced scientific equipment, and that the number of ships be increased 90 per centum within the next ten years;

(f) shore facilities commensurate with an expanded program of basic research be constructed in order to derive maximum knowledge from observations and collections made at sea;

(g) development and utilization of deep-diving manned submersibles be expedited to facilitate maximum accomplishments in both basic and applied oceanographic research at all depths;

(h) mineral research be undertaken on the ocean floor with a view to present or ultimate utilization of the untapped resources that lie beneath the ocean; and

(i) extensive scientific investigations be made on the effects of radioactivity in the oceans including the genetic effects of radiation upon marine organisms, the inorganic transfer of radioactive elements from seawater to the sediments, and the circulation and mixing processes which control the dispersion of introduced contaminants in coastal and estuarine environments and in the open ocean;

(4) recommends that in order to coordinate the programs of the various agencies some method of interagency cooperation should be developed, possibly through an Oceanographic Research Board or Commission; and

(5) recommends that cooperation between the United States and other nations in oceanographic research and exchange of data should be considered on a carefully supervised and reciprocal basis.

Oceanography was one of the few special fields singled out for mention in a statement released December 27, 1958, by President Eisenhower when he made public a report of his Science Advisory Committee concerned with strengthening American science. As background, the President introduced the report by noting:

More than a year ago a many-pronged effort was launched to underwrite the strength of American science and technology as one of our essential resources for security and welfare. At that time, I asked my Science Advisory Committee to

make a study of ways in which the Federal Government could best serve this objective.[16]

The report itself is prefaced by remarks concerning the role of the Federal Government and then goes on to identify the challenge of new frontiers:

> With more emphasis on basic studies, the Government would be able to nurture research in wholly new areas of science * * *. In other areas of science * * * progress has been handicapped by lack of tools and facilities adequate for the job at hand and of adequate numbers of trained personnel. * * * Meteorology is just one example of a field deserving greater attention. Some others are geophysics, radio astronomy, biophysics, linguistics, and social psychology. *Oceanography is another promising field which has received inadequate attention.* For the study of the oceans the United States has only a few research vessels, all inadequately equipped. A vessel specially designed and constructed for oceanographic research has not been built in this country since 1930.[17]

[16] "Science Program—86th Cong.," Senate Report, No. 120, p. 91.
[17] Ibid., p. 94.

IV. New Perspectives on Research in the Sea

Along with the relationship of the sea to national security, another set of factors is emerging which defines certain unprecedented aspects of oceanic research. The first of these is recognition that *the ocean has three rather than two dimensions, and that the parameter of depth presents new challenges and offers new promise that attention only to the surface and boundaries of the sea could never satisfy.* Second, the same technology that has evolved to render a new urgency to oceanic research may also be the technology that for the first time may make practicable some solutions to the new demands. Third, the global quality of the oceans which has been recognized in purely geographical terms, also has implications for international cooperation and coordination in studies of the sea which are cited by many as offering unusual promise for promoting the peaceful interests of the United States as well as for maintaining this country in a position of world leadership. International cooperation in science reached an unprecedented level in 1957–58 through the International Geophysical Year, and oceanography was shown to be one of the fields of science that especially benefited by a global approach.

Further crystallizing the recent attention to proposals for long-range and far-reaching programs of research and development in the sea and giving them a more driving sense of purpose appears to be a belief that now for the first time the goals can be achieved.

A. Depth—The Unexplored Dimension

In a sense, man is ambivalent in his attitude toward the sea—coupled with the salubrious joys of seashore recreations, man is well aware of his own physiological limitations that preclude prolonged immersion. People have drowned in 6 inches of bath water. Thus, without benefit of mechanical artifice, man could penetrate *onto* the sea only short distances from the safety of a shoreline, and *into* the sea for only short distances and exceedingly brief intervals because of the very necessity of air supply. Ventures onto the sea were accompanied by hazard, by losses of life and property, and often by extreme discomfort. The impact of crashing waves is indeed impressive, and for many generations, man dreamed of exploring the quiet waters beneath the turbulent, hostile surface, and utilizing them for transportation.

Recently technology has greatly changed attitudes toward descent within the sea. Self-contained underwater breathing apparatus (SCUBA) are now commonplace, and the devotees to personal underwater exploration, numerous and widespread. With flippers and air supply, man has a new mobility in shallow water, and the colors, forms, variety, and dynamics of underwater life, so well documented by Cousteau, have provided rich rewards.

On a more significant scale, the submarine provides the vehicle by which man may enter deep as well as shallow waters, in greater numbers, with the advantage of auxiliary power for performing under-

water operations, and for extended endurance. It was the development of nuclear propulsion that released the submarine from its dependence on a periodic replenishment of air for diesel recharging of batteries. Nuclear power thus gave the U.S.S. *Nautilus* unprecedented performance in sustained, high-speed operation while fully submerged. Other exploits followed of the U.S.S. *Nautilus, Skate* and *Sargo* in traversing the North Pole under the ice cap and, more recently, of the *Triton* in circling the Earth, a sea route of 36,000 miles, without completely surfacing. The technological capability of exploring and even operating in shallow water is well proved. Recently, too, Piccard and Walsh proved in the submersible vehicle *Trieste* that man can descend to the very deepest regions of the ocean, some 35,800 feet near Guam. But the *Trieste* is a "bottom dunking" device with limited capabilities other than for depth seeking. It is not a submarine. What then is the potential for more ambitious undertakings in deep water?

True submarines consist of thin, cigar-shaped shells that, like surface ships, develop their buoyancy from displacement of sea water. Through the use of ballast, usually sea water, their weights can be delicately adjusted so as to be heavy enough to sink when submerged performance is desired, or to operate near or at the surface.

In general, these operations have not been very deep. Jane's "Fighting Ships of the World" for 1957–58 notes that the U.S.S. *Nautilus*, which at that time was dramatizing the spectacular achievement and merit of nuclear power, is able to operate only at depths of 700 feet. The working depth for combat submarines has always been regarded by the U.S. Navy as classified so that this figure may represent only an order of magnitude.

The significance of this limitation is evident from data regarding the depths of the ocean set forth in Table 1. There, the oceans are expressed in percent of their total area versus depth. From this information, it is clear that the *Nautilus* could operate to the bottom in less than 5 percent of the ocean. To operate deeper would require a stronger and essentially, a heavier hull, so that increased depth would have been achieved at the penalty of some other performance characteristic. As far as the *Nautilus* was concerned, its capabilities of sustained high speed when submerged even when operating within that depth were considered by naval designers as satisfactory.

The point, however, is that depth is essentially an unexplored dimension of the sea. It is just being realized that it may be as significant as the more familiar wavy surface or shoreline. In these depths, in fact all the way to bottom, there is evidence of marine life; perhaps not so prolific as in the regions nearer the surface where photosynthetic processes maintain a rich supply of organic food. There are certainly minerals in the sea water at depth, on and in the bottom. The water at these depths is just as much in circulation as are the surface currents, and it is the vertical "upwelling" that resupplies mineral content to support life at the surface. At depths on the order of several thousand feet, a "deep sound channel" develops that, by processes of reflection between water layers of different density and the bottom, serves as a duct for long-distance sound transmission. By way of example, a small explosive charge detonated in the Indian Ocean was heard with underwater hydrophones 9,000 miles away in New York.

These so-called deep sound channels have clear implications for long-range, passive, acoustical detection of underwater objects.

This phenomenon may serve to introduce the contention by those interested in the sea that the most urgent reason for penetrating the full depths is military. The sea conceals its contents. A stone thrown into the water almost instantly disappears. In clear, unruffled water, its trajectory may be followed visibly to depths of perhaps ten or so feet, but then is lost from view. It is this opaqueness of water that gives the submarine its enormous advantage of concealment, and the concomitant property of surprise.

TABLE 1.—*Depth of ocean versus expanse*

Depth in feet:	*Percentage of ocean less than indicated depth*	Depth in feet—Con.	*Percentage of ocean less than indicated depth*
1,000	8.5	15,000	60.0
2,000	10.5	18,000	90.0
3,000	11.9	21,000	99.0
6,000	15.9	24,000	99.5
9,000	20.5	35,800	100.0
12,000	34.5		

Source: Kossinna, Erwin. 1921. Die Tiefen des Weltmeeres. Berlin Univ., Institut f. Meereskunde, Veroff., N.F., A. Geogr.-naturwiss. Reihe, Heft 9, 70 pp., 1921.

Even with exceedingly sensitive devices to measure the sub's disturbance of the Earth's magnetic field, detection from the surface becomes more and more difficult as the craft dives deeper. *It may take a deep-diving sub to catch a deep-diving sub.*

Beginning in World War I, efforts to render the sea more transparent were focused on the use of underwater acoustic devices, either hydrophones to listen passively, or active devices which emit sharp pings of sound and depend on echoes to reveal otherwise silent and occulted targets. Such devices, attached to the underside of searching surface ships, on killer subs, or dunked from blimps and helicopters, all suffer from the same limitations—the relatively short range at which sounds may be detected. Obviously, those situated near the sea surface also suffer from the distracting effect of background noise from the waves themselves. Nevertheless, the major effort today is still concentrated on the use of underwater acoustics to detect, classify, and track, and if necessary, control the weapons which will destroy a hostile underwater boat.

Nature itself, however, has conspired to defeat the success of some of these systems. Sound propagating in the depths is reflected or refracted when the sound waves strike the interface between two layers of sea water at different temperatures and densities. Submariners have learned how to exploit this phenomenon so as to hide their boats completely. Another aspect of this game, which takes on the aspect of two men groping for each other in the dark, is the deliberate quieting of the boat so that it will not reveal itself, thus forcing an opponent to utilize active sonar which gives away his location.

All of these actions suggest a relatively close proximity of submarine to search vehicle. *Military strategists may thus consider how much more difficult the problem of detection would be if the entire sea were a military arena and searching were necessary throughout the entire volume of ocean, not simply at the limited depth near the surface in which submarines now operate.* They may also choose to consider

the far more challenging problem of being able to identify a submarine or even bottom crawler that has secreted itself amongst the hills and valleys of an irregular bottom, or is simply sitting on a "sea mount."

Not knowing that an aggressor is nearby is perhaps the most disconcerting aspect of this potential. Just as higher altitude performance for aircraft has paid off, whether it be for combat or for surveillance, the extended depth capability of submarine suggests the same potential benefit. But the "proof of the pudding" must lie in experiments with deep-diving vehicles not yet in being.

Not to be forgotten in this discussion of operation at depth is the desire for manned vehicles for oceanographic research itself. The advantages of having an observer in the environment he is studying, rather than relying on instruments at the remote end of a cable towed by a surface ship, is obvious, and this aspect of oceanographic research is expanded in Section VI. But a sample of the extended research capabilities which attend availability of manned vehicles for research in the deep ocean is a prelude to combat operations at depths. A listing of projects necessary for developing knowledge of the deep ocean, presented by the bathyscaph crew to the House Science and Astronautics Committee, is appended.

Finally, there is the matter of engineering operations on the ocean bed. Exploring for oil and minerals, much less the development of any such resources, is sure to be enhanced by availability of manned vehicles that can operate from the surface to the bottom, anywhere.

There is thus an emerging set of military as well as nonmilitary demands to study the entire ocean, and as a related objective, to develop an entirely new generation of vehicles for operation far deeper than is currently possible with contemporary submarines.

Deep Ocean Research Planned for Bathyscaph[18]

1. OCEANOGRAPHIC PROJECTS

(a) Submarine geology:
- (1) Topographic studies—study of features too large to photograph and too small to study easily with echo sounders.
  - (a) Channels at mouth of LaJolla and Scripps Submarine Canyon.
  - (b) Study of "levees" on channels in San Diego Trough.
  - (c) Study of detailed topography of upper continental slope—50–500 feet.
  - (d) Study of topography of continental slope between borderland and deep ocean.
- (2) Mass physical properties of sediments.
  - (a) "In situ" sound velocity and absorption measurements.
  - (b) Strength and penetrability study of sediments.
  - (c) Slope failure and slump studies and relation to topography sediment types.
  - (d) Temperature studies in sediments.
- (3) General studies.
  - (a) Geology and hydrology of closed basins.
  - (b) Areal distribution and environmental studies of phosphorite and other minerals.
  - (c) Geology, topography, and hydrology of borderland basin sills.
  - (d) Dynamic processes affecting the distribution of sediments and sedimentation processes.

(b) Physical and chemical oceanography:
- (1) Physical properties of the sea.
  - (a) Temperature structure.
  - (b) Density.
  - (c) Water transparency.
  - (d) Light penetration.
- (2) Chemical properties of the sea.
  - (a) Salinity.
  - (b) Dissolved gas.
  - (c) Dissolved solids.
  - (d) Suspended colloids.
  - (e) Radioactivity (cooperative study with other naval laboratories).

(c) Biological oceanography:
- (1) Distribution of animal and plant life.
  - (a) Plankton and relationships to sound transmission.
  - (b) Organic detritus and relationships to sound transmission.
- (2) Biological noises.
  - (a) Kinds, distribution, and intensity of biological noises.
  - (b) Biological noises and target classification.
- (3) Ecological studies.
  - (a) Ecology and sound transmission—physicochemical relationships of deep-water and marine organisms.
  - (b) Benthonic organisms and their relationship to food chains, influence on topography and sedimentation, and possible influence on the concentration of radioactive materials that occur in limited quantities in the water mass.
  - (c) Deep-sea organisms and sound generation.
  - (d) Distribution and quantity of bioluminescence.

2. ACOUSTIC PROJECTS

(a) Continuous sound velocity profiles (continuation of the measurements planned for Project Sonus to be conducted in June 1960 in the Marianas Trench).

(b) Deep scattering layer investigations correlating acoustic measurement, visual observations, and photography.

(c) Study of sound field levels in the sea from near surface sources at various frequencies.

[18] "Frontiers in Oceanic Research," op. cit., pp. 28–29.

(d) Reciprocal case of shallow receivers and source at various great depths.
(e) Investigation of ambient noise types, levels, vertical, and geographical distribution.

Is operation at greater depths possible?

For vertical mobility, a submarine is designed so that its buoyancy produced by displacement of sea water is just about equal to its weight; moreover, the weight includes the items of hull structure, of mechanical plant and of payload in terms of weapons, or scientific equipment, etc. At the same time, the hull structure must be sufficiently strong to resist the crushing effects of water pressure, which itself increases linearly with depth: about 1 pound per square inch of pressure is added for each 2¼ feet of depth below the surface. Thus, any requirement for increased operating depth involves the use of stronger and, ordinarily, heavier hulls. The requisite balance between buoyancy and weight can thus be met when the hull is heavier only if other components are made relatively lighter. This may imply smaller power with diminished speed, or less payload. One performance characteristic must be traded for another, and in the past, insofar as submarine designers were concerned, depth was not a primary choice because it was believed to entail unacceptable penalties in weight.

Structural designers of submarines were thus faced with the same dilemma that confronted designers of aircraft which have similar weight-penalty problems. Solutions were thus sought from research on materials and engineering technology for either other substances out of which the hull could be built or other geometric forms that displayed an increased ratio of strength to weight. By such means, increased depth could be achieved in a submarine without undue forfeiture of other performance characteristics. The vital necessity of pursuing a deep-diving adversary or taking advantage of depth for enhanced listening range is now considered by some naval experts to force an eventual increase in depth capabilities, even at the sacrifice of certain other capabilities.

Prompted by studies of the Committee on Undersea Warfare, National Academy of Sciences—National Research Council, the U.S. Navy, through the Office of Naval Research and the David Taylor Model Basin, began a program of research on the strength of hulls for deep diving submarines about 2 years ago.

B. THE EMERGING OCEAN TECHNOLOGIES

The barrier which has historically restrained man from submarine operations at all depths in the ocean now shows promise of being dissolved by technological advancement. High-strength steels, high-strength aluminum alloys, fiberglas reinforced plastic, titanium, and beryllium as engineering materials show the promise of producing structures whose strength-to-weight characteristics will permit their use in submarine hulls for operation 10 to 20 times deeper than the depth cited for the *Nautilus*. Exactly what will be the scientific as well as practical benefits are unpredictable, but recent experience has dramatically shown the advantage of priority in scientific achievement. Vehicles in increased number, either self-buoyant as are submarines or bottom crawlers, and even fixed underwater stations in which men may live and work safely, constitute some of the emerging realities that now make possible an attack on the entire ocean.

The development of new, more versatile, more highly sensitive and more compact instruments is a second major element that will implement exploration of the sea. Crude, bulky mechanical instruments with limited sensing or recording capabilities can now be replaced by compact, transistorized units to measure almost any quantity in or under the sea better than their predecessors. Moreover, contemporary techniques with instrumentation permit the transmission of such data over great distances either directly by wire or telemetered by radio.

By way of example, the synoptic picture of the sea over a wide area can now be potentially developed through large numbers of floating buoys in conjunction with aircraft. Each buoy can be fitted with devices to measure sea state, wind, and weather and to record these data on magnetic tape. Although widely distributed, these buoys may then be interrogated by an aircraft flying over the entire matrix of buoy stations, and the buoy-stored information telemetered to the plane for permanent recording. With the magnetic tapes of the buoys automatically wiped clean, they are then ready to record a second sample. The location and velocity of subsurface currents, together with their temperature, salinity, etc., can be measured similarily using "Swallow" buoys that are designed to drift at predetermined mid-depths and can also be remotely interrogated for stored intelligence.

The significance of synoptic data, both on or beneath the surface, cannot be overemphasized because the sea involves a complex dynamic mechanism which is changing with time everywhere. Its behavior can thus be revealed only if a large number of measurements over a large area are recorded simultaneously.

It is thus clear that any description of the ocean will entail huge quantities of numerical data. Even if the ocean were to be described at any one instant, this number of simultaneous observations would be enormous; but to describe these changes and moreover, to determine relationships among the different variables would until recently be so herculean a task as even to discourage the attempt.

Automatic computational devices which have found wide application in other fields have an untapped potential in relation to the ocean sciences. Enormous quantities of data may be stored, selectively retrieved, indexed, correlated, and even subjected to interpretation. By standardizing methods of recording, data collected in the future anywhere in the world and by any nation could readily be incorporated into a single data center and thus the knowledge represented by these data would be cumulative rather than compartmented. A similar attack is being made on the atmosphere through improved data collection and interpretation in order that weather may be forecast more accurately. Because of the ultimate relationship of weather and climate with the atmosphere and the oceans, correlation of meteorological and oceanographic data is essential.

Simultaneously with the engineering developments outlined, scientific research in relevant collateral fields has been so accelerated that studies of the ocean may now utilize a rapidly increasing base of fundamentals from physics, chemistry, geology, and biology. Advances include the use of radioactive dating techniques for the study of the "age" of "fossil" water at great depths as well as of geological specimens, and the use of radioactive tracers for other experiments such as beach erosion.

The range of such benefits is so great that only the barest mention is possible in this report. Nevertheless, the future increased rate of transfer of this background to a field such as oceanography opens up exciting prospects of achievement.

C. OPPORTUNITIES FOR INTERNATIONAL LEADERSHIP

All too often the terms "international cooperation" and "international leadership" become catch phrases representing a vague beneficent philosophy which, through some unspecified mechanism, is expected automatically to yield progress toward peace and maintenance of the United States as a world power. The international aspects of oceanic research have been stated in such terms that the opportunities for accomplishment through multilateral action appear unusually fruitful.

In the first instance, oceanography, as is true with any science, is international in character. Physical laws which describe circulation of currents in the ocean and exchange of heat with the atmosphere, which define the ecology of some particular marine life, are universal. Discovery by any one nation freely benefits all nations. The ocean sciences, however, have the additional attribute of involving large areas of the world in a single phenomenon. This would certainly be dramatized by the worldwide rise in sea level due to any melting of the polar icecaps, or by the propagation of tidal waves due to subterranean earthquakes. For a better understanding of the oceans and their contents, it is necessary to make measurements from a large number of stations throughout the world simultaneously. Such synoptic studies can be successfully conducted only through coordinated programs involving many ships, many measurements, and many observation stations throughout the world. Obviously, any such program could be accomplished only by joint efforts of participants from many different countries. Such a multilateral attack on worldwide scientific problems was the very essence of the International Geophysical Year which was concluded in 1958 with such success. The study of the oceans was appropriately included in this IGY program. At the conclusion of the IGY, the International Council of Scientific Unions which had fostered its organization formed a Special Committee on Oceanic Research (SCOR), about whose activities more is noted subsequently.

Congressional reaction to IGY is reflected in the following passages from a report of the House Select Committee on Astronautics and Space Exploration:

> One of its major political and human phenomena is that the IGY organized the scientific world into a single unit for the advance of knowledge about the nature of the universe. Barriers of language, nationality, even politics, and mutual cold war antagonisms were in this massive quest for exact data mostly surmounted. Some 30,000 scientists and technicians, in 66 nations, for 18 months worked more or less in total concert and in freedom to organize, discover, proclaim, scientific truth.[19]

The Select Committee also concluded that—

> The IGY has been of great value in itself by contributing to more and better knowledge and control of the human environment. * * * The IGY illustrated that scientific progress can no longer be left to individuals working alone, but must be supported by a partnership of Government, business enterprise, educa-

[19] "The International Geophysical Year and Space Research." Staff Report of the Select Committee on Astronautics and Space Exploration, H. Doc. 88, 86th Cong., p. 33.

tional institutions, philanthropic foundations, and the masses of the people. * * * The IGY is also a striking example of the feasibility and fruits of international scientific cooperation. Moreover, a comparison of its work with the previous unaided scientific efforts of individual nations indicates that such cooperation is actually necessary to certain scientific achievements.[20]

This global characteristic of oceanic research has been underscored by the need for international cooperation on common problems. For example—

Artificially created radioactive materials have been introduced into the sea by the testing of nuclear weapons, by the disposal of low level waste products from the operations of nuclear reactors and by disposal of low level laboratory waste. * * * The adoption of standards and regulations to prevent pollution of the sea by radioactive materials is obviously an international problem. The duty of nations to cooperate to this end has been spelled out in Article 25 of the Convention on the High Seas adopted at Geneva in April 1958.[21]

Many scientists believe that the oceans may be safely utilized for limited and carefully monitored disposal of wastes, but unless there is control over disposal by all nations, in the presence of subsurface currents, dumping of radioactive materials far at sea may have adverse and even dangerous effects on "downstream" neighbors.

Yet another reason cited for international cooperation on common problems is the concern with its living resources.

These resources occur both on the high seas where they are common property and in the coastal waters where there exist certain national property rights and where some nations claim preferential rights of fishing to distances beyond the limits of the traditional territorial sea. Since the fish populations pay no heed to man-made geographical boundaries, the management of both the living resources of the high seas and of coastal waters requires international collaboration. The necessity for management of the sea fisheries arises because a fish resource may be affected substantially by an intense fishery: indeed the resource may be fished so intensively that the total harvest is less than that which could be obtained by more moderate use. * * * The Convention on Fishing and Conservation of the Living Resources of the High Seas adopted at Geneva in 1958 is expected to come into force in the near future. It establishes criteria and mandatory procedures for handling the scientific problem, and thus lays a foundation for handling the political and economic problems.[22]

Still a third significant factor in the international aspects of oceanic research concerns the utilization of scientific discovery as a step toward preventing international disputes and even as a step toward disarmament:

Nations must find some way to live with the new threat of nuclear-powered submarines armed with long range weapons. The transparency of the air allows us to locate, identify, and track potentially hostile surface warships. The opacity and vagaries of the sea make it much more difficult to detect and identify submarines. In recognition of this, international law requires submarines to navigate on the surface and show their flag when passing through the territorial sea of another state. * * * Under present international law, a submerged submarine outside territorial waters in peace time is not violating any law or amenity, and is not subject to attack. Thus the probability will become steadily greater in the future that an international mischief-maker will be able with impunity to initiate a nuclear holocaust. It may then become necessary to make a change in international law which would require a submerged submarine to surface and identify itself on demand or be subject to attack. For enforcement of such an international agreement a submarine surveillance system might be essential throughout the high seas. The specifications for this system would necessarily be based on international cooperative research much as fisheries treaties are now based on the research of international commissions.[23]

[20] "The IGY and Space Research," op. cit., p. 36.
[21] "Oceanography 1960–70; International Cooperation," NASCO Report, Chapter 10, p. 3.
[22] NASCO Report, Chapter 10, op. cit., p. 3.
[23] NASCO Report, Chapter 10, op. cit., pp. 4–5.

Precedence has been established for such international cooperation on disarmament as it relates to methods of detection of clandestine nuclear tests. Agreement has not been reached, however, in part because of unsettled scientific questions concerned with "decoupling" of blasts which could be conducted in an underground cavity to defeat detection. Progress in such disarmament leans heavily on science and on agreement among scientists of different nations. The United States depends on the nuclear-propelled missile-launching submarine as an important element in our "mix" of deterrent weapons; but we are vitally concerned with the Soviet submarine threat, and the day may come when both nations agree on mutual efforts to sustain a surveillance system that would provide mutual guarantee against stealthy attack. It is likely that any such system would depend on the placement of location devices throughout the world, and the effectiveness of these in providing an assured surveillance of the ocean depends, to a great extent, upon further research on techniques themselves as well as on knowledge of the sound transmission and physical properties of the water in various geographical areas of concern.

Any such system would need a sensitivity sufficient to detect not only submarines at current depths of operation but even at much greater depth. Such a system might also have to detect bottom crawlers that might even be more difficult to locate in the irregular terrain of certain parts of the ocean. While this country must pursue a course of preparedness, the eventuality of international agreement on such matters, perhaps through cooperative study, was implied by NASCO.

Yet another frequently mentioned element of international oceanography lies in leadership in cooperative scientific expeditions. In the first instance, the resources of and in the high seas are the common property of all nations so that exploration on a cooperative basis makes more likely exploitation in the future free of national rivalry. Second, an element of prestige attends leadership in such operations, both in science and in world affairs.

Statistics indicate that the number of scientists and engineers in the United States is already exceeded by those in the U.S.S.R. and that the disparity is growing. One primary consolation lies in the intellectual resources of the free world which, in the aggregate, outnumber those in the Sino-Soviet bloc. There are thus continuing and even increasing reasons why the United States must depend upon and foster contributions by scientists in friendly countries and it might be expected that success in this activity would be better assured by the maintenance of the United States in a position of scientific eminence. An example of a contrary situation lies in the events attending formation of the Committee on Space Research (COSPAR), a sister organization to SCOR. Upon termination of the IGY, continuation of international research in outer space was planned through COSPAR. However, at its first meeting in London in 1958, the Soviet Union, discovering that representatives nominated under the original charter would come primarily from Western powers, insisted that it would not participate unless the Committee operations were revised so as to reflect achievements by the Soviets in the space sciences. As a consequence, the permanent organization provides for an Executive Council which includes two Vice Presidents, one chosen from a slate

presented by the United States and the other by the U.S.S.R. Four additional members will be chosen in equal numbers from lists prepared by these two Vice Presidents. From this experience, it is clear that the U.S.S.R. was able to utilize its stature in space research to insist on (in this case proportionate) membership in international scientific organizations. Should the U.S.S.R. develop similarly in the ocean sciences, world leadership which now resides in the United States may well migrate to the Soviets, with consequent loss in prestige in the scientific community.

An early opportunity to foster such international projects, in this instance in the Indian Ocean, has been proposed under the auspices of SCOR.

> International cooperative attacks on little-known oceanic areas will stimulate oceanographic activities in the surrounding countries and so accelerate the increase of our knowledge. An example is the plan for a combined assault on the Indian Ocean, the largest unexplored area on Earth, by the Special Committee on Oceanic Research of the International Council of Scientific Unions. This area is of particular interest to physical oceanographers because seasonal reversals in wind direction, that are not known elsewhere, provide opportunity for studying the transient state in the wind driven currents. In this program, scientists from the Northern Hemisphere and scientists and students from the bordering countries could take part cooperatively in a series of simultaneous expeditions. Thus, the expeditions not only would serve their primary purpose of exploration but also would have a lasting effect in encouraging and developing the marine sciences and fisheries in those countries. It is estimated that at least 16 ships from 11 different countries could be enlisted.[24]

The SCOR program tentatively includes participation by Australia, Denmark, France, Germany, United Kingdom, India, Japan, Union of South Africa, United States, and U.S.S.R. Some of the costs are expected to be borne directly by participating nations, some to be solicited from international agencies and private foundations. At the present time, those planning the International Indian Ocean Expedition are hoping for equal contributions from the U.S.A. and the U.S.S.R. which would represent roughly 80 percent of the total cost. Detailed plans are to be discussed at the SCOR meeting in Copenhagen, July 9–20, 1960.

Expeditions of all types incidentally provide a new means of "showing the flag," and the traditional appearance of naval vessels as a symbol of strength and good will may find effective supplementation.

The importance of U.S. participation in international programs was also recently discussed by Dr. Roger Revelle, Director of Scripps Institution of Oceanography:

> No one nation can find out unaided all that it needs to know about the oceans. International cooperation in the study of the seas is essential, just as it has proven essential in studying the atmosphere and the stars. The United States has an unparalleled opportunity to exert world scientific leadership in developing this cooperation. Both before and during the International Geophysical Year, American oceanographers played an important role as scientists in planning and carrying out the initial steps in international cooperative oceanography. They were backed with funds appropriated for the IGY by Congress. New opportunities are now arising and these will also require funding. To prepare for these opportunities, action by government agencies is now needed.
>
> An intergovernmental conference has been called by UNESCO for next July in Copenhagen. At this conference it is hoped that interested governments will be able to work out ways in which they can cooperate effectively in charting the floor of the sea, measuring its properties, and the movements of its waters, and in surveying the seas' living resources. I recently attended the preparatory meeting for this conference in Paris as one of four United States delegates.

[24] NASCO Report, Chapter 10, op. cit., pp. 1–2.

Representatives of 25 nations were present, including a four-man Russian delegation. It was evident that the U.S.S.R. is determined to push very hard on their share of any international program that may be decided upon at Copenhagen. But it also appeared that they would be willing to exchange a great deal of the data to be obtained and to work cooperatively in planning surveys and intercalibrating instruments.[25]

[25] Statement by Roger R. Revelle for the Senate Committee on Interstate and Foreign Commerce, April 21, 1960.

V. Potential Programs of Research

Considering the broad geographical expanse of sea and the relatively limited knowledge about it, those working in the field have noted that a potent frontier exists in all of the oceanic sciences. A shopping list of projects can easily be assembled covering studies of the sea, the bottom, its contents, its relationship with the continents, and with the atmosphere. A sampling is presented in this section, mainly to suggest to the reader something of the technical content which the oceanographers refer to in discussions of an accelerated level of effort.

Although necessity is the mother of invention, necessity may also be considered the burr under the saddle which stimulates research. All of the areas discussed subsequently are considered attractive by scientists because concerted study would fill existing gaps of knowledge; truly basic research is conducted without thought of application. Nevertheless, the applications in many cases are so striking that their omission would render this element of background incomplete.

In introducing these examples, one additional fact seems evident. The relatively limited effort that has been applied in the past has created a unique opportunity for the future—an opportunity in terms of a high expectation of important discovery, either geographic or scientific. Many of these discoveries, through their public knowledge, will benefit all countries of the world. That nation associated with the discovery is the initial beneficiary. This becomes particularly important in terms of the application of results for defense. No more dramatic example exists than basic discoveries of nuclear fission which, far from being only of interest to the academic world, created a revolution in warfare.

A. Military Oceanography

The application of oceanography to military or defense requirements includes—

(*a*) the design and specification of new equipment to take maximum advantage of the properties of the oceans;

(*b*) tests of new equipment to meet operational requirements;

(*c*) tactical use of equipment; and

(*d*) strategic planning wherein knowledge of the ocean can be used to select the time and location of military operations.

During World War II, oceanographic research and information found intensive application in both amphibious and undersea warfare. The success of beach landings depended on accurate knowledge of conditions in the surf and at the shore zone, data on wave heights and direction, and on tides. Loading and unloading of cargo was obviously conditioned by such information. The Normandy operation was threatened by problems in predicting simply wave heights.

Vastly oversimplified, the underlying technical foundation of warfare *under* the sea is the property of water that limits penetration of light and electromagnetic radiation. On the other hand, sound is transmitted better through the ocean than through the air.

Undersea warfare is thus a deadly game of blind man's buff in which the winning side is most likely to be that with most acute hearing.[26]

Temperature gradients, layers of plankton which scatter sound, the noise of the sea itself, complicate the problem, but the potential for research is clear. The problem of "seeing without being seen" is a major challenge to the Navy today. Making the ocean transparent by underwater surveillance systems, while being able to operate free of detection is a bivalent goal.

On land we have networks of radars which plot the positions of all aircraft to prevent collisions and to detect intruders. It cannot be too long before we will have the counterpart of these crisscrossed networks in the sea—submarine beacons radiating sound beams for the guidance of underwater craft as the lighthouse uses a light beam to guide ships on the surface. Sound receivers must be coupled together in a vast underwater spider web of millions of miles of cables which, like our radar surveillance in the air space, can keep track continuously of normal comings and goings, yet single out any stranger in our midst. To identify friend from foe is one of the most difficult underwater problems the Navy has.

All efforts to make the seas transparent for military purposes have a value more lasting than the short-term gains of armed conflict by helping us to understand the ocean.[27]

Having defined military oceanography and suggested its urgency, the reader will nevertheless note that studies referred to subsequently by the National Academy of Sciences and by the Navy pertain mainly to sectors of oceanographic research which exclude immediate defense applications. Developmental aspects of military oceanography, like any other application, depends upon generation of basic knowledge; when this fund of knowledge is deficient, as has been said to be the case by those studying the sea, potential for military as well as scientific breakthroughs is very high.

B. BASIC RESEARCH

In a way almost unprecedented in history, peoples throughout the entire world have had their interest aroused in the universe around us. Man suddenly appears on the threshold of penetrating the reaches of outer space with sufficient instrumentation and eventually with manned vehicles to observe, measure, and interpret processes of nature involving the Earth, the Moon, other planets, and eventually the entire galaxy. To understand this complex system, however, something of its origin, of its evolution and of its destiny—a great deal needs to be known concerning the Earth itself.

For example, one of the unsolved questions is whether the ocean water and atmosphere were formed early in geologic time or whether they grew slowly, perhaps squeezed out from the interior of the planet. The formation and distribution of the continental masses and oceanic depressions are by no means clear. The most that can be said is that, and this was noted earlier, water in its liquid state distinguishes the Earth from the other planets; the Earth is just the right distance from the Sun in terms of radiant energy it thus receives, and the size of the planet and associated gravitational field are such that both an atmosphere and water in liquid form are retained.

The cliché that "past is prologue" must be considered to apply rigidly in the case of natural laws. Predictions of the future events

[26] "Oceanography 1951," op. cit., p. 18.

[27] "Turn to the Sea," by Athelstan Spilhaus, Committee on Oceanography, National Academy of Sciences, 1959, p. 11.

in nature depend upon comprehension of antique processes. The possibility of ice on the Antarctic melting, as it once must have, and raising the level of the sea by perhaps 200 feet would spell doom for many large cities of the world. At the moment, the cycles of climate and sea level which are known to have existed in the past cannot be explained.

Along with curiosity about the origin of the Earth is the related question of the origin of life itself. Apparently life began in the oceans. Every major biological family has its most primitive members still in the oceans. There is speculation that such life began when the sea was a warm broth of organic and inorganic materials which, over the eons of time, ultimately produced that complex molecule capable of self-reproduction. By sampling life in more detail in the sea and particularly at greater depths, not only can the taxonomy of species be clarified but the actual processes which produced evolving forms and affected the rate of development may be discovered. The ocean shields its life from cosmic rays which can produce mutations, and it is possible that other forms of life, such as the ancient coelacanths which represent the link between fish and vertebrates on land, may be discovered.

In finer detail, there are great mysteries as to how certain types of sea cucumbers concentrate the mineral element vanadium in amounts 100,000 times that trace in the ocean itself, and how the oyster concentrates copper. The presence of other biological organisms or "trace elements" in the sea in unbelievable dilution may, nevertheless, be found significant in the entire complex of biological balance. Perhaps these substances possess medicinal properties that may explain freedom of undersea life from the ravages of cancer and other diseases.

But what is most significant is the elemental and oft repeated fact that the oceans cover 71 percent of the surface of the Earth and represent the greatest basic area of undeveloped knowledge of the world around us. The first step in any scientific attack on a problem is *observation* and it is this process of observation that has been so strongly emphasized in proposals for an increased program of research. Then significant contributions can be made from the more fundamental fields of physics, chemistry, biology, and geology in relating these observations to the cumulative fund of scientific knowledge already developed and in generalizing these observations through what are termed "natural laws."

C. OCEAN SURVEYS

> Maps are the basic tools of all the sciences that deal with the Earth. To exploit and fully use the oceans, we must first map them systematically. * * * During the past 100 years, the land areas of the Earth have been mapped in ever increasing details but accurate maps of the ocean basins exist only from their shallow rims. For the 90 percent of the ocean floor that lies below the continental shelf, only the gross features of shape and structure are known. Existing maps of the ocean basins are comparable in accuracy and detail to land maps published at the beginning of the 18th century. In addition to the bottom topography and the associated gravitational and magnetic fields, we need to map in three dimensions the synoptic, seasonal and average distribution of water temperature, density, chemical properties and currents. In the biological realm, we should map the fertility of the sea and the abundance of marine organisms in all ocean areas.[28]

[28] "Oceanography 1960-70, Ocean Surveys," NASCO Report, ch. 7 (draft), p. 1.

By an extension in hydrographic surveying, the way is open for direct geographical discovery. Today, this carries a new significance. It has become clear from the naming of the invisible radiation belt around the earth after its discoverer, Dr. James A. Van Allen, and of major features on the backside of the Moon by the Soviets who first photographed it from an artificial satellite, that an element of prestige attends such accomplishments. The British National Committee on Ocean Bottom Ventures has recommended that geographical names should be given wherever possible to all major features and that personal or ship names should only be given to secondary features.[29] It is unlikely, however, that there would be agreement on this process despite the possible effect in reducing international rivalries. Subsurface countercurrents in the Pacific have recently been discovered by the American, Cromwell and so named. Such acclaim is one of the professional rewards for discovery. *In a tense international climate, where even small items relate to national prestige, such naming of geographical features in the ocean may be significant.* Eventually, discoveries and the national rivalries that may attend such processes may take on an entirely different aspect when the enterprise involves the joint collection of data by several nations simultaneously.

Finally, it might be noted that as activities in the oceans grow, the problem of determining precise location will become increasingly significant. The location of property boundaries offshore is now accomplished by standard geodetic techniques, referenced to land marks. But, far at sea, this may be exceedingly difficult. If activities in the sea materialize according to views of many working in the field, then reference lines may be literally run on the bottom of the ocean and either bottom topography or anomalies in the Earth's magnetic or gravitational field utilized for precise undersea navigation and location. Lines marked on the ocean bottom by an accurately steered vehicle might persist for many years because of the relative freedom from currents and the exceedingly slow rate of sedimentation.

D. STUDY OF NEW RESOURCES

1. Biological

Among the problems now confronting human society that have aroused widespread interest and discussion and yet seem among the most baffling is the failure of the majority of the people in the world to have enough to eat. Human population is rapidly growing and in some regions has far outstripped available food supply. Food deficiency of one kind or another exists everywhere, even in the United States. Despite the best of intentions and the application of logic, the problem does not appear soluble simply by shipping excess food from the richer to the poorer regions. Thus, even with benefits of agricultural science, production does not now satisfy world needs.

Many food economists have pointed to the sea as the most likely source of protein enrichment of human diet. The seas are filled with rich fauna and flora drifting at the surface, or in layers at intermediate depths; there are meadows of plants and swarms of large and small animals grazing or preying upon one another. While there are 20,000 species of fish alone, only a few species are caught, and only part of those caught are used.

[29] "Proposed Names of Features on the Deep-Sea Floor," by Wiseman and Ovey, Deep Sea Research, 1954–55, vol. 2, p. 93.

The desirability of expansion in the use of sea resources to help satisfy human needs for food is self-evident and in a contemporary era, wherein science and technology have been effectively utilized to solve similar problems, it is natural to look to research in marine biology, in oceanography, and in exploratory fishing.

Information is presently lacking on the abundance and availability of fishery stocks, rhythmic seasonal changes, and sporadic fluctuations. With such information, fishing could be less hunting and more cultivation. We know now that large fertile areas exist in the sea in the North and South Pacific, in the North and South Atlantic and in the southern oceans. Productivity of the Indian Ocean, however, is said to be less certain, and this is unfortunate considering the needs by nations on its borders.[30]

The South Atlantic, on the other hand, has very large fertile areas so that countries bordering this area that currently suffer protein deficiency might well be immediate beneficiaries of the stimulation of marine fisheries and fishery research.

> For each stock, the following needs study: the geographic distribution throughout the year; the abundance; the growth rate; the migratory habits; the spawning habits, spawning season, and fecundity; the relation between fishing rates and productivity; the mechanism by which fluctuations in the environment affect natural mortality; features of the environment which affect distribution.[31]

The interrelations among species of fish are vastly complex and tangled; one lives upon the other. The abundance of the stock is greatly influenced by the abundance of its prey, its competitors, and its predators. Man is one of the predators and fishing harvests can be depleted in the sea by overfishing, as can any other natural resource, for want of efficient management and conservation.

Biological research concerned with utilization of the sea resources involves study of the environment and the manner in which chemical, physical, and biological characteristics of sea water influence its fertility. The sea is in constant motion both horizontally and vertically and these influences are geographically much more far-reaching and much more subject to the dynamics of the environment than is the case with the agricultural uses of land. There, of course, the farmer deals with the vagaries of weather, but at least he is aware of this influence varying as a function only of time. In the sea, the resource and environment are both in motion. Fish spawn in one place and mature in another, and during a life cycle may migrate great distances.

This environment is an ecological unit which, as a part of the sea, has peculiar properties that satisfy the physiological requirements of a population or a number of species which live together there. Because of the vastness as well as the lack of control over the deep ocean, systematic cultivation of marine life in a controlled environment has been most seriously considered only in shallow bays or estuaries. At present, they are probably the only parts of the sea which can be farmed. The fertility of brackish inshore water is such that when properly manipulated, "aquiculture" as such technology is called, should be profitable, as for example, in the cultivation of oysters.

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[30] The particular potential for research offered by studies of biological resources of the sea has had the benefit of an unusual study. Under sponsorship of the Conservation Foundation, an independent organization established to promote greater knowledge about the Earth's resources, Lionel A. Walford has undertaken a comprehensive and incisive examination of the problem. His impressions and recommendations are set forth in a stimulating and informative book on "Living Resources of the Sea," published by the Ronald Press Co., New York, 1958.

[31] "Living Resources of the Sea," op. cit., p. 48 (with permission of Ronald Press).

A number of imaginative suggestions have been made concerning means of increasing supply of marine life from the sea, including the artificial circulation of water rich in life-sustaining chemicals from great depths. Numerous other proposals are bound to arise but in all cases their feasibility and practical development require research. Any such research, entirely apart from increasing stocks of fish, might go far toward eliminating the changes in abundance and availability which make the fishing industry so uncertain. These fluctuations are, to a great extent, unaccounted for. For example, menhaden, a herring-like fish, may yield no oil in some years and in others as much as 60 gallons per ton of fish. In a single month of one year it has been observed to vary between 5 and 40 gallons per ton. There is now evidence that trace elements may be as vital to life in the seas as on the shore, but there are many unknowns concerning what comprise life-stimulating properties.

In this connection, sea water appears to contain certain antibiotics which, under some circumstances, may be important. To nonmarine bacteria, sea water is curiously antagonistic, and they cannot be cultivated on nutrient agar prepared with it. In fact, sea water kills 80 percent of the coliform organisms in sewage within a half hour, and it has been proven that it is not the salt content which produces this effect. Thus, even in the sea, the battle between micro-organisms appears to continue, despite the fabulous dilutions which the vast quantities of sea water afford.

The uncertainties of success in fishing have clearly made this an unattractive area for capital investment. As a consequence, the industry itself has had but limited funds to invest in fishery research, and the responsibility for improvement in fisheries has been left almost wholly to Government. Walford, in reviewing this problem, has noted—

> Most people who have thought about the matter agree that even in the most advanced countries, fishing, as compared with other food-producing occupations, is still at a low level of development. Fishermen are like hunters and gatherers in primitive societies. Their techniques and apparatus—hook and line, traps and nets—are essentially the same as they have always been. Fishing is everywhere a difficult occupation, and although fishermen in a few special situations are sometimes prosperous, most of them are perennially poor. * * * Perhaps new methods need to be devised, radically different from anything that has been used. These are most likely to be achieved if based on the principle of behavior of marine animals. Research to discover these principles is fundamental to development of the science of fisheries.[32]

Activities beneath the surface lie well concealed from human view. Thus, studies of how fish live and swim, how they react to artificial stimuli, such as sounds, electrical currents, bright illumination, and turbulence require direct observation. Yet, this is now technically feasible for, as mentioned earlier, man may now descend into the ocean at almost any depth, safely, to observe marine species in their natural environment. The Soviets have equipped one of their submarines, the *Severyanka*, with portholes for such observations. The Bureau of Commercial Fisheries has contemplated such projects in efforts to study the Pacific tuna. Modern technology affords opportunities now as never before to study fish and the process of fishing and thus to reduce the elements of luck and of lore, and to minimize the chance association which fishermen superstitiously

[32] "Living Resources of the Sea," op. cit., p. 98.

attribute between quite unrelated events and exceptionally good or bad fishing.

Such studies might well confirm whether fish detect food by sight, smell, or hearing and thus what bait might be most productive. Observations might determine how they respond to nets; whether perhaps certain species successfully elude this type of trap. Some fish are known to respond to underwater noise and it would be entertaining, indeed, to consider the possibility of whistling fish into range of a fishing vessel.

With deepwater vehicles, behavior of marine life can be observed in its natural environment, an important consideration because this behavior is vastly altered if the fish is removed to an aquarium for observation. Even automatic cameras or underwater television iconoscopes would permit vastly improved observations.

Also deserving further study are the sudden mass mortalities of fish which occur sporadically throughout the world. Frequently this phenomenon is accompanied by "red tides," wherein the surface of the sea water is heavily discolored and whatever material causes the coloration destroys millions of pounds of fish. Outbreaks on the West Coast of Florida extend in bands 20 miles wide. Fish entering these patches of water would surface, whirl about crazily, turn on their sides, float a while belly up, then sink to the bottom. With an onshore wind, people on shore were affected by a burning sensation to the nostrils, eyes, and throat. The economic consequences of a "red tide" are serious for both local fisheries and those catering to the seaside tourist trade.

Having noted earlier the primitive techniques of sea fishing, it is apparent that fishing vessels and techniques all over the world have evolved by trial and error, although frequently well adapted to local conditions. The Bureau of Commercial Fisheries has done a great deal to guide technological advancement in this area but study of these fishing ships remain incomplete. Since these craft are usually designed by individual boatbuilders rather than naval architects, the choice of lines, general arrangement, powerplant, etc., may often be selected on the basis of tradition rather than technology. In particular, the performance of a vessel in a seaway rather than still water assumes real significance in terms of the number of days that a fishing boat may be effectively kept at sea and used in rough weather. To be sure, the performance at sea is a function of the skill of the crew, but a great deal of information is needed to improve qualities of stability, seaworthiness and sea kindliness from actual observations.

The vessels which are noted later in this report as needed for oceanographic research can simultaneously serve the needs of the fishing industry in that some of them may serve as prototypes for fishing. This may appear to be a unique twist in that oceanographers universally complain about the inefficiency of the current fleet engaged in research because almost without exception the vessels are converted from other purposes. The important point, however, is that oceanographic research ships also have an optimum requirement for seaworthiness and sea kindliness. The need to utilize every possible day at sea for oceanographic observations and the related requirements for a stable platform will carry over into the area of fishing. Thus, full scale experiments in the design of new oceanographic research ships could well lead to a new generation of hulls from which the

fishing industry would itself benefit. This process may be all the more significant where the economies of fishing and the lack of funds for research make it unlikely that experimental fishing boats could be funded by themselves.

Whereas most emphasis in marine biology relates to zoological organisms, vegetation of the sea also is deserving of attention. Marine algae have some human nutritional value, and it is interesting to note current research on the possibility of continuous production of algae to sustain man in space. Algae now eaten throughout the world are seldom a delicacy, but certain properties of agar, for example, favor its use not only for its own sake, but as a preservative for other foods where refrigeration is lacking.

The United States has for some years maintained a policy of technical assistance to the undeveloped countries of the world. Studies in marine biology suggest themselves as an emerging area wherein the fruits of research may be literally as well as figuratively beneficial to all mankind.

An entirely different objective now motivates studies of the porpoise and other sea mammals. Although the porpoise has been something of an entertaining curiosity in the sea, scientists concerned with behavior of marine life have recently come to recognize that at least this particular mammal bears more than passing investigation. In the first instance—

> the relative intellectual standing of various animals cannot be accurately assessed because the validity of all proposed tests is open to question. Most zoologists who have studied porpoises are deeply impressed both with the porpoise's ability to learn almost incredibly fast on some tests and the wide variety of its emotional responses.[33]

The porpoise is apparently able to swim far faster than can be computed possible from analysis of his body form and energy for propulsion available from metabolism of food. Some scientists believe that the porpoise is able to accomplish this feat by swimming without loss of energy through turbulence, a condition which, if imitated, would permit the propulsion of ships at either far higher speeds or lower power than presently required. It has also been observed that the porpoise incorporates a type of underwater sonar. Apparently, even when its eyes are covered with suction cups, it can traverse a course spread with barriers of all kinds, sensing in some fashion their presence and maneuvering to avoid collision. Many porpoises have been trained to perform in captivity.

All of these facts suggest that creatures of the sea have evolved, in general, with little or no close observation by man and that many physiological as well as physical processes of life in the sea bear extensive study. The fruits of this research, like that of any other field, are unpredictable.

2. Mineral Deposits

Production of oil from offshore deposits and extraction of magnesium from sea water are well known examples of oceanic minerals. However, large deposits of mineral nodules were discovered on the ocean floor almost 100 years ago. More recent gleanings from the ocean bed have revealed their presence in tremendous numbers, and most of them contain high concentration of such minerals as manga-

[33] Christian Science Monitor, Apr. 30, 1960.

nese, cobalt, nickel, and copper which, one day, may be in scarce supply. "On the average, the nodules run to something like 20 percent manganese, 15 percent iron; but some of the richer deposits may yield as much as 45 percent manganese, 1 percent cobalt." [34]

John Mero, a graduate student at the University of California, has been studying the possibility of recovery for some time. First, he says that the usual deep sea research technique of dragging a metal dredge over the bottom could be used, but might have practical disadvantages. As a possible alternative, he suggests a kind of underwater "vacuum cleaner" that would scoop up nodules as it runs over the bottom and pump them to a barge on the surface. * * * Here is a legal problem to match that involved in the conquest of space. Who owns the mineral rights under the high seas? Can any one nation or group of nations stake a claim and fend off all comers? Could a mining company be guaranteed any kind of lease or title by its national government? Or will an international agency, perhaps within the UN, take over jurisdiction? [35]

This question of ownership was treated in the Convention on the Continental Shelf at the United Nations Conference on the Law of the Sea in Geneva, 1958. Article 1 defines the Continental Shelf in a fashion that differs from common geologic usage:

as referring to the seabed and subsoil of submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters or, *beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas.* [Emphasis added.]

That these boundaries extend far beyond the usual interpretation has been suggested by G. E. Pearcy, geographer of the Department of State, writing on "Geographical Aspects of the Law of the Sea." [36] Pearcy notes that article 6 of the Convention defines the boundary—

where the same Continental Shelf is adjacent to the territories of two or more States where coasts are opposite each other * * * in the absence of agreement, * * * as the median line, every point of which is equidistant from the nearest points of the baselines from which the breadth of the territorial sea of each State is measured.

There is thus the "territorial sea" of breadth yet unsettled, but now considered variously as 3-, 6-, or 12-miles, depending upon pronouncements of various nations. (The United States has always favored the narrowest limit here to preserve freedom of the seas, particularly in the vicinity of straits.) Both the water in the territorial sea, and land underneath come within sovereignty of the coastal State. Beyond that boundary, however, the oceans and their surface and contents are regarded as high seas, declared a *res communis;* i.e., owned in common. But the ocean bottom and its mineral resources, according to this 1958 convention is *everywhere defined as belonging to the coastal State*—with the median boundary instantly defined, everywhere, sometimes existing at mid-ocean. When underwater mining becomes practicable, this convention may be put to an immediate test, but the question of ownership is at least clarified over prior, vague interpretations.

3. Energy

The greatest source of energy in the sea lies in the water itself. Hydrogen, one of the elements in water and thus in enormous abundance in the oceans, may be considered the fuel from which energy may be someday derived, imitating the natural process of nuclear

[34] Christian Science Monitor, Mar. 9, 1959, p. 13.
[35] Ibid., p. 13.
[36] "Geographical Aspects of the Law of the Sea," G. E. Pearcy, Annals, Assoc. Amer. Geographers, vol. 49, March 1959, No. 1, pp. 1–23.

fusion that occurs on the Sun. Should current research efforts succeed, man would have a virtually inexhaustible store of energy, but the quest is long and arduous.

Still another possible source of energy from the sea has been proposed by taking advantage of the difference in surface and bottom temperature. It has been said that almost 35,000 times the existing annual energy consumption of the world is delivered annually to the Earth in the form of solar radiation and since most of the Earth's surface is covered by ocean, a major portion of solar energy is absorbed by the sea.[37]

The temperature at depths below which sunlight does not penetrate, on the order of 1,200 feet, is ordinarily around 40° F. In the tropics, surface temperatures of 80–90° are common. Theoretically, this temperature difference could be utilized to drive a properly designed turbine, but it would operate at low thermal efficiency because the temperature differences are low. Quite obviously the amounts of energy so extracted are unlimited. The major question is whether such systems are economically attractive.

Finally, there is the possibility of extraction of power from the twice daily rise and fall of the tides—such as has been proposed many years ago for Passamaquoddy.

> It is natural that man should look for means of harnessing some of the power of the tides for his own benefit and small tide mills have been operated in a few suitable localities for centuries. Many plans for tidal power stations such as the Severn Barrage scheme have been drawn up, but only one project has so far reached the construction stage. This is the French scheme for the Rance Estuary in the Bay of St. Malo which is designed to have a capacity of 340 megawatts and is due to be completed in 1960. The main difficulty in the development of tidal power is that even with large tidal ranges, the hydraulic head available is comparatively small and large areas of tidal water would have to be enclosed, at high capital cost.[38]

E. METEOROLOGY AND CLIMATOLOGY

The close relationship of the oceans to processes in the atmosphere has been noted. Some additional details may make clearer why questions of weather forecasting and climate control depend on understanding of the sea.

In the first instance, the Earth may be regarded as having a certain heat budget which is related to energy gained from solar radiation versus losses by reflection and reradiation in outer space. The difference, obviously more at the Equator than at the poles, is absorbed by the atmosphere, by the land, and by the oceans; but, by virtue of their physical properties and vast size, the oceans are the primary recipients. This energy is then distributed by many processes; by evaporation as the liquid water changes to vapor, and condensation as it then drops as rain, or by circulation through both vertical and horizontal ocean currents.

The atmosphere itself contains energy and there is a continuous flow back and forth between atmosphere and ocean at the interface. Some of this exchange may be mechanical rather than thermal for energy transmitted by surface winds to the sea apparently is the mechanism largely responsible for surface currents. Scientists thus attempt to develop equations in which all of the elements in this

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[37] "Design of a Sea Thermal Energy Power Plant" by Asa Snyder, *Solar Energy*, Dec. 1959, pp. 49–54.
[38] "The Oceanic Tides," by K. F. Bowden, The New Scientist, Sept. 3, 1959, pp. 348–351.

exchange of energy can be accounted for and the long-term manifestations of climate understood.

Eventually, man desires to control climate, to enjoy the salubrious effects of mild and predictable weather. It would seem that the sheer mass of this natural phenomenon would defy adjustment. On the other hand, scientists are confronted with many processes in which a condition exists of incipient instability. Like sitting on a fence, only relatively small forces or investments of energy are necessary to cause the process to swing radically from one side to another.

If these processes could be controlled, the impact for constructive purposes by their application to marginal lands, thus to feed an increasing population of the future, will be significant. The military use of climate control carries with it more sinister implications. The nation that could influence the rainfall of another might well control the destiny of the world.

F. TRANSPORTATION AND COMMERCE

The advent of nuclear power and the exploit of nuclear-propelled submarines in traversing the North Pole beneath the icecaps and entirely around the world submerged mark developments which may preface significant innovations in sea transportation. While for a combat submarine, nuclear propulsion has demonstrated advantages over orthodox systems for prolonged submergence at high-sustained speeds, nevertheless, this successful application has stimulated much imaginative thinking of other military and, equally important, commercial uses. Studies have revealed the practicability and eventual economic feasibility, of submarine tankers for commercial transportation of bulk liquid cargo. However, the advantage of submarines in fuel economy at high speed because of lower hull resistance (freedom from dissipation of energy in forming bow waves) is balanced by higher costs of construction of ship and port facilities so the arguments for commercial submarines are not overwhelming.

Submarine transportation, however, would extend trade routes under the ice. The presence of sea ice in the Northern Hemisphere is well known. In summer, this ice retreats from the northern boundaries of Russia, Canada, and Alaska sufficiently that round-the-world navigation is possible at latitudes between 70° and 85°. All year, all weather transportation by travel under the ice might have very entertaining possibilities. If relations with the Soviets improve, trade would certainly increase and polar routes are obvious. Even more immediate, commercial routes between certain major ports would be reduced by Arctic operation. The standard distance between New York and Tokyo is 9,638 nautical miles, but it is only 7,512 miles via Baffin Bay, northern Canada, and the Bering Strait. From London to Tokyo, the nautical distance is 10,958 miles versus 7,530 miles via the northern route. On the other hand, the distance from New York to Seattle via the Panama Canal is 5,874 miles versus 7,212 miles via the northern route, which would thus render this operation unattractive unless the Canal were closed.

Any operations would benefit by an improved knowledge of the sea; in this case, of sea ice, and of bottom topography. Currents, for example, could possibly be utilized by submarines to increase their

speed or reduce power requirements just as the jetstream is utilized by high flying aircraft.

Another system of sea transportation now being enthusiastically investigated is the use of hydrofoil craft. Such vehicles are essentially ship hulls fitted with underwater wings. When the ship is propelled with sufficient speed, the wing or foil develops forces that lift the hull up out of the water and thus permit its horizontal motion, free of most of the frictional losses that the hull normally sustains. Not only are higher speeds thus attained, but the hull is far less subject to rolling, pitching, and heaving, and otherwise responding to the random motions of the sea surface; the hydrofoil cuts through the waves and is designed to adjust itself automatically to their local variation provided they are not too severe. Any such operation, of course, presupposes knowledge of the sea surface, and long distance routes for hydrofoil operation would strongly benefit by wave forecasting in the same fashion that ship routing now so benefits.

In this regard, mention should be made of the behavior of conventional ship hulls in the sea. In general, the hull form has been optimized through empirical tests with small scale models so as to develop the most economical performance in a smooth sea or in regular waves. The ocean itself, however, is irregular and it is only now becoming realized that it is possible to develop a mathematical description of this apparently random and confused pattern. As a consequence, the effects of the sea may be subject to far more scientific analysis, either as they produce motions of the ship as a whole or as they may induce stresses in the hull. With improved information, the shape of the hull and internal construction might be so improved that a ship would prove far more comfortable riding and able to sustain the impact of seas than is presently the case. In storms, ships would then be able to continue on course and at speed, rather than to slow down and head into the wind as is now common practice.

In this regard, recent use has been made of forecasting sea state so that merchant ships may select the route which, although not geometrically the shortest, would still permit the vessel to travel between two ports in the least time. Such operations are now standard practice for the Military Sea Transport Service, saving approximately 10 percent in time at sea with increased passenger comfort.[39]

The same benefit has been found by improved information on sea ice. Whereas the cost from ice damage and delay to MSTS vessels was estimated in 1951 to be about $17 million, it has apparently been reduced through improved oceanographic data and ice prediction to less than $1 million per year.[40]

Digressing for a moment to the general subject of economies resulting from oceanic research, even larger amounts have been saved by studies of marine borers that degrade ship hulls and marine structures; both lives and property have been saved by study of tidal waves that lead to warning systems. Further study of economies resulting from oceanic research is beyond scope of this current report but obviously a factor in justifying increased expenditures.

[39] "The Oceans as the Operating Environment of the Navy," paper by John Lyman to ONR symposium, San Diego, Calif., March 1959.
[40] Ibid.

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G. RADIOACTIVE WASTE DISPOSAL

The oceans have been historically utilized for disposal of continental refuse and the same reasons that have made the oceans attractive for ordinary waste products has made them highly useful for disposal of low-level radioactive waste.

The new problem, however, is the potential hazard to health, normal physiological and genetic processes through the accidental return of radioactive substances from the sea to man or to other biological organisms.

Great precautions have been taken to stay well within the safe capacity of the seas to receive such material and to assure that mixing with the ocean water is at such a rate that even future generations will not be adversely affected.

Present practices of disposal in the sea involve only low-level waste. These are broadly classified as waste containing up to the equivalent of millicurie quantities of activity per gallon. They are distinct from high-level wastes, such as those obtained from the processing of spent reactor fuels which may contain hundreds of curies per gallon. These low-level wastes are generated in university and industrial laboratories, hospitals, and research institutions licensed by AEC to use relatively small quantities of radioactive material.[41]

As the industrial and military uses of nuclear processes increase, as is certain to be the case in the future, the problem of disposal becomes increasingly important and is considered, by those responsible for health and safety, to require a great deal of research on the oceans themselves:

> Vigorous programs should be started for the purpose of determining the circulation and mixing processes which control the dispersion of introduced contaminants in coastal and estuarine environments and in the open oceans. * * * A program should be pursued, aimed at determining the inorganic transfer of radioactive elements from sea water to the sediments. * * * Studies should be made of the effects of living organisms on the distribution of radioactive elements introduced in the sea. * * * The genetic effects of radiation upon marine organisms should be studied.[42]

The problem takes on an even different hue when considering not the deliberate but accidental introduction of radioactive substance into the sea through detonation of nuclear weapons for harbor construction, or through accidents with nuclear-propelled ships or with artificial satellites involving nuclear elements which fall into the sea. These same problems are obviously critical on land, but except for material which is distributed downwind, dangerous radioactivity is likely to be highly localized. In the sea, however, the problem is quite different. Knowledge of currents may permit selection of safety measures in the event of an accident, even if processes of containment are impracticable.

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[41] "Radioactive Waste Disposal Into Atlantic and Gulf Coastal Waters," NAS-NRC Publication 655.
[42] NASCO report, ch. 1, p. 20.

H. THE AESTHETIC QUALITIES OF THE SEA

> From birth, man carries the weight of gravity on his shoulders. He is bolted to the Earth. But man has only to sink beneath the surface and he is free. Buoyed by water, he can fly in any direction—up, down, sideways—by merely flipping his hand. Underwater, man becomes an archangel.

This poetic description by Jacques Cousteau of man's recent personal penetration of the sea characterizes a readily overlooked relationship of man and the oceans. There are now over 1 million skindivers who have found the sea a source of relaxation and recreation—a source even of inspiration. A major industry has evolved to provide these enthusiasts with aqualungs and other specialized breathing apparatus. This development further characterizes emerging cultural patterns in which paid vacations play an increasing role. More people will be heading for the beaches to swim, to fish, or to skindive, and considerable investments can be expected of facilities for their use.

Oceanic research enters this picture prominently in terms, for example, of the populations and distribution of marine life, not only for commercial fisheries, but for sport. The popularity of resorts quickly passes when the sands are eroded, sharks invade areas previously populated only by human swimmers, or the normally heavy stocks of fish disappear; the economic depression which attends such changes have marked effects on these local areas.

Probably as many as 5.4 million Americans relax by fishing in the ocean and this number appears destined to increase. The importance of this activity has been cited by the Sport Fishing Institute in their support of pending legislation.

VI. The Present Posture in Oceanography—An Inventory

Assuming that the previous excerpts of speeches and reports are an accurate indication, there appears to be strong sentiment in favor of increasing oceanic research, both to strengthen our defense posture and to revitalize the civilian uses and scientific investigations of the sea. A question very naturally arises as to just what is the current level of scientific effort that is held to be presently inadequate?

As information background for those not familiar with the field, and as a basis for evaluating specific NASCO, TENOC, and ICO proposals for the next 10-year program, efforts were made to collect the most recently available statistics—to identify and inventory current activities. (Initials refer to National Academy of Sciences, Committee on Oceanography; "Ten Years in Oceanography" study by the Office of Naval Research; and the Interagency Committee on Oceanography.) Since the general program objectives and technical content of oceanic research were outlined previously, attention is directed in this section only to the mechanism of conducting oceanic research. These ingredients are identified in terms of—

A. The organizations conducting research.

B. Manpower.

C. Facilities.

D. Funding.

E. Federal agencies having oceanographic responsibilities, and their coordination.

Some brief details are also offered on comparative programs in the U.S.S.R. and on U.S. participation in international programs.

Many of these data have been extracted from nine published reports (issued as "chapters,") discussed in Section VIII, or from unpublished studies of the Committee on Oceanography of the National Academy of Sciences, in the main, developed through a questionnaire directed in the spring of 1958 to all laboratories known to be engaging in one phase or another of the marine sciences. Parenthetically, this compilation represents one of the rare cases wherein one particular field of science, and in this case a multidisciplinary field, has been so comprehensively dissected. Additional details have been generously furnished by other government agencies; in particular, the Geophysics Branch of the Office of Naval Research.[43]

It should be noted that most of the NASCO data refer to fiscal year 1958. Significant trends have been identified wherever more current information was available, especially if there was evidence of major deviations from the 1958 base. In many cases, original data have been reclassified or combined to suit the needs of this report.

The terms of reference of these data are in one sense arbitrary and require some amplification. It is well known that the term "research" is subject to many interpretations, and that grave difficulty attends

[43] Particular acknowledgment should be made to Richard Vetter, NAS-NRC, and to Arthur Maxwell, ONR, for assistance in developing unpublished data used in this report and for their suggestions and criticism in review of the manuscript.

efforts to separate "pure" from "applied" research and further related categories of "development," and "test and evaluation." Among those actively participating in the field of ocean sciences, there has been general agreement that *the sector which they refer to as being undernourished is that of research, both basic and applied, not development. It is this sector that has been inventoried.*

The "development" sector of activity, although not inventoried, has been discussed in this report and is separated into two major categories: military oceanography, and commercial engineering projects in the sea. The definition of military oceanography has been treated earlier, and little need be added, except to note that certain of the statistics presented necessarily include some unfilterable aspects of military oceanography; in every case, these are identified.

Other than fishing, industrial activities in the sea which deserve mention to preserve complete perspective, fall into two subcategories. In the first instance, there is a considerable volume of offshore oil exploration which involves the same type of hydrographic surveying, geological mapping, research on seismic instruments, etc., as is accomplished in the general research activities to increase knowledge of the sea floor generally. However, because these data are almost always considered proprietary, and are thus not contributed to the general clearinghouse of public information about the Earth, these activities have not been inventoried in this report as part of the national research effort in oceanography.

The second type of industrial activity regards engineering construction projects in the sea. In some respects, these are the commercial analogues to what has been termed "military oceanography," and are excluded from the inventory for the same reason—they are so highly developmental in character and involve only scant generation of new knowledge. Because these projects comprise an emerging technology that feeds on the basic and applied research of the sea with which this report is primarily concerned, some details of the more exciting and imaginative projects now underway have nevertheless been included in Section IX.

Finally, one other footnote important to this tabulation of the national capabilities for research in the sea, should be amplified—the contributions of naval laboratories conducting "inhouse" programs over the full spectrum of the marine sciences. Certain of these have had continuing activities in oceanography that include projects sufficiently basic, and of an unclassified nature, to have been included by NASCO in their 1958 survey. A number of other laboratories, however, have so recently directed their attention to this field of research, or maintain programs so strongly flavored by defense application that they have not been surveyed by NASCO. Wherever possible, these naval laboratories and some details on their type of activity have been listed, but quantitative data on the level of their capabilities have not been available.

In noting that this inventory is expressed in strictly *quantitative* terms, the *qualitative*, more intangible, characteristics of a national program are not adequately reflected. Statistics fail to record scientific accomplishments, the degree of skill of the research staff, and of effectiveness of the research management; the distractions of effort to solicit funds or preserve continuity of programs; the data cannot indicate the sophistication of program, or lack thereof; the adequacy or

obsolescence of either shore or seagoing facilities. It was not the purpose of this report, however, neither would it be possible nor appropriate to evaluate the performance of oceanographic research activities as could be done, for example, in terms of the effectiveness of a weapon system, in meeting its specified performance requirements. Nevertheless, the qualitative parameters of research are highly important because the need for more research funds and manpower can sometimes be in part ameliorated by a more effective utilization of the supply on hand. This type of self-appraisal was undertaken by the NAS Committee on Oceanography only incidentally.

A. ORGANIZATIONS CONDUCTING RESEARCH

Oceanography is a very recent area of research activity in the United States. To be sure, hydrographic surveys were first systematically organized on a worldwide basis some 100 years ago, but the systematic collection of scientific knowledge about the sea dates only from approximately 1920. At that time, there was a mere handful of laboratories; but the number has increased almost tenfold in the intervening 40 years, having doubled during the most recent 15. There are now approximately 70 laboratories of various size with the growth in number shown in Table 2.

In this table, these marine laboratories have been classified according to the type of sponsoring agency—as between Government owned and operated laboratories (state or Federal), universities, and nonprofit independent research organizations. Virtually none of the research is currently undertaken by industrial or commercial establishments.

This tabulation reflects the exceedingly rapid postwar growth, from 1945 to 1950, during which time the number increased by 70 percent. Such a precipitous expansion matches the pattern in other scientific fields—thus representing the pent-up needs for basic research that had been deferred during the pressure of wartime activity. This expansion also reflects the boom in GI student enrollment and in corresponding increase in facilities for instruction.

Although further growth continued from 1951 to 1958, it was somewhat slower and, in fact, from 1958 to 1960 growth appeared to have been completely arrested.

TABLE 2.—*Number of marine laboratories in the United States and territorial possessions showing growth from 1920 to 1960*

Sponsoring agency	Reporting year					
	1920	1930	1945	1950	1958	1960
State	0	2	3	8	9	9
Federal [1]	2	4	12	19	26	26
University	4	7	14	25	30	30
Other [2]	2	4	4	5	5	[3] 5
Total	8	17	33	57	70	70

[1] Not including naval laboratories concerned exclusively with military oceanography.

[2] Mainly non-profit corporations engaged in marine research funded by private capital, or by endowments provided by foundations.

[3] Very recently, a number of industrial concerns, either by broadening the scope or diversification of their research activities, have added small groups devoted to the marine sciences. These programs, however, cannot be considered to have matured to the status of a "Marine Laboratory."

Source: "Oceanography, 1960–70, Marine Sciences in the United States in 1958", NASCO Report, chapter 12, p. 1.

At first glance, this latter event is rather remarkable in light of the sharp expansion in scientific research and development that occurred during these 2 years, both in terms of Federal expenditures and in terms of the number of new organizations entering the research and development field. For example, Federal obligations for basic research increased from $1,034 million for fiscal 1958 to $1,603 million in fiscal 1960—an expansion of roughly 60 percent. During this same time, an even greater increase was occurring in the development areas, and growth in "research and development" across the board grew from $5,878 million in 1958 to $8,148 million in 1960.

Subsequent analysis may reveal, however, that the average size of these 70 marine laboratories is so very small relative to research facilities in other fields that the number and continued proliferation of separate organizations is not necessarily an index of the size or effectiveness of a research program. In the field of oceanography, the large number of small units appears to reflect the many different educational institutions having a limited curriculum in the marine sciences, or of small fisheries laboratories having cognizance over strictly local problems.

Details of the 70 largest organizations undertaking oceanic research in the United States are given in Tables 3 and 4. They are listed in a sequence according to size of annual expenditures (for fiscal 1958). In Table 3, laboratories are identified according to type of organization, using two different criteria. In the first instance, they are listed as to type of performance component according to whether they are:

Educational Institution Laboratory.
Educational Institution Research Center.
Non-Profit Laboratory.
Non-Profit Research Center.
Government-owned, Government-operated Laboratory.
Industrial Laboratory.

For purposes of this report, the *Educational Institution Laboratory* is taken as a research unit embedded in a university wherein the laboratory and staff are utilized both for purposes of instruction and for research. The *Educational Institution Research Center*, on the other hand, represents an element within a university complex whose operations are devoted predominately, although not necessarily exclusively, to research rather than to instruction or a combination thereof. *Non-Profit Laboratories* include those organizations such as private foundations, philanthropic groups, and other institutions which do not distribute earnings to private stockholders and which undertake oceanic research as one part of a broader program encompassing numerous fields. As distinguished from Non-Profit Laboratories, *Non-Profit Research Centers* devote their efforts primarily, if not exclusively, to a limited spectrum of research and, in this case, predominately oceanography. *Government-owned and operated Laboratories*, following the usual definition, represent research units staffed by Government employees, funded and administered directly by a Government agency. In some cases, these organizations may be housed on a rental basis within the facilities of a non-Government entity. *Industrial Laboratories* represent the research units of profit organizations which legally distribute their earnings to individuals or to other firms.

All of the 70 organizations in Table 3 have been identified according to type of performance, and in addition Government laboratories have been further delineated according to the particular sponsoring agency.

The second type of classification of these organizations in Table 3 follows the definitions by the NASCO Committee as to whether or not they comprise a large or small university laboratory, a large or small fishery laboratory, or a Naval unit. In this context, the distinction between "large" or "small" relates to whether annual funding is greater or less than $300,000. This size budget also coincides with the demarcation of laboratories operating sea-going ships. The differentiation as between universities, fisheries, and Naval units was derived from the type of program in which they were primarily engaged: those focused explicitly on marine biology were called fishery laboratories; those having broader interests were termed university laboratories; those deriving their funds almost exclusively from Naval sources, whether or not they were Government-owned and operated, were termed Naval laboratories.[44]

These same 70 oceanic research organizations have been further classified in Table 4 according to their type of program and scope of geographic interest. The program content is implied to a great extent from the types of research previously described in Section V. The delineation by geographic interest is, in most cases, directly linked with the facilities on hand. Any interest in deep-sea research would be obviously academic without the availability of a sufficiently large and seaworthy research vessel. Other distinctions between deep water, coastal and local boundaries of interest are self-evident.

TABLE 3.—*List of oceanographic research laboratories according to type of organization*

Name [1]	Type of performance components						Type of organization, NASCO report				
	Educational-institutional laboratory	Educational-institutional research center	Nonprofit laboratory	Nonprofit research center	Government laboratory (parent organization)	Industrial laboratory	Large university laboratory	Small university laboratory	Large fisheries laboratory	Small fisheries laboratory	Navy
Scripps Institution of Oceanography, La Jolla, Calif.		X					X				
Woods Hole Oceanographic Institute, Woods Hole, Mass.				X			X				
Lamont Geological Observatory, Palisades, N.Y.		X					X				
Marine Laboratory, University of Miami, Virginia Key, Miami 49, Fla.		X					X				
Pacific oceanic fishery investigation, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, Honolulu, Hawaii					FWS				X		

See footnotes at end of table, p. 63.

[44] Reference has been made to "military" oceanography as that portion of marine science directed toward research and development of a specific hardware item or system having direct military application and falling in the realm of classified security information. The Navy units identified in the NASCO report participate in programs of military oceanography, but they also participate in Navy-sponsored programs having less specific application drawing on a broader base of scientific fundamentals and partly or fully unclassified. Military oceanography, per se, was not included in the NASCO report, whereas the latter type of Navy-sponsored research has been.

TABLE 3.—*List of oceanographic research laboratories according to type of organization*—Continued

Name [1]	Type of performance components						Type of organization, NASCO report				
	Educational-institutional laboratory	Educational-institutional research center	Nonprofit laboratory	Nonprofit research center	Government laboratory (parent organization)	Industrial laboratory	Large university laboratory	Small university laboratory	Large fisheries laboratory	Small fisheries laboratory	Navy
Alaska Department of Fish and Game, Juneau, Alaska					State				X		
Department of Fish and Game, State of California, Sacramento, Calif					State				X		
Department of Oceanography and Meteorology, Texas A. & M., College Station, Tex	X						X				
Pacific salmon investigation, Bureau of Commercial Fisheries, Seattle, Wash					FWS				X		
Bureau of Commercial Fisheries, Woods Hole, Mass					FWS				X		
Department of Oceanography, University of Washington, Seattle, Wash	X						X				
Gulf fishery investigations, Bureau of Commercial Fisheries, U.S. Fish and Wildlife, Galveston, Tex					FWS				X		
Inter-American Tropical Tuna Commission, Scripps Institute of Oceanography, La Jolla, Calif					X [2]					X	
Chesapeake Bay Institute, Johns Hopkins University, Baltimore, Md		X						X			
South Pacific fishery investigation, La Jolla, Calif					X					X	
Arctic Research Laboratory, Fairbanks, Alaska				X						X	
Fisheries Research Institute University of Washington College of Fisheries, Seattle, Wash		X				X		X			
Marine Laboratory, Texas Game and Fish Commission, Rockport, Tex					State					X	
Department of Meteorology and Oceanography, New York University, New York, N.Y	X							X			
North Atlantic Exploratory Fishing and Gear Research, Bureau of Commercial Fisheries, Boston, Mass					FWS					X	
Hancock Foundation for Scientific Research, University of Southern California, Los Angeles, Calif		X						X			
Virginia Fisheries Laboratory (College of William and Mary), Gloucester Point, Va					State					X	
Pascagoula Fisheries Laboratory, Bureau of Commercial Fisheries, Pascagoula, Miss					FWS					X	
Narragansett Marine Laboratory (University of Rhode Island), Kingston, R.I	X							X			
Chesapeake Shellfish Investigation, Bureau of Commercial Fisheries, Annapolis, Md					FWS					X	
International Pacific Halibut Commission, University of Washington, Seattle, Wash					(3)					X	

See footnotes at end of table, p. 63.

TABLE 3.—*List of oceanographic research laboratories according to type of organization*—Continued

Name [1]	Type of performance components						Type of organization, NASCO report				
	Educational-institutional laboratory	Educational-institutional research center	Nonprofit laboratory	Nonprofit research center	Government laboratory (parent organization)	Industrial laboratory	Large university laboratory	Small university laboratory	Large fisheries laboratory	Small fisheries laboratory	Navy
Oceanographic Institute, Florida State University, Tallahassee, Fla.		X						X			
Northern Pacific Exploratory Fishery and Gear Research, Seattle, Wash.					FWS					X	
Institute of Marine Science, University of Texas, Port Aransas, Tex.	X							X			
Hawaii Marine Laboratory (University of Hawaii), Honolulu, Hawaii		X						X			
Atlantic Herring Investigation (Bureau of Commercial Fisheries, Boothbay Harbor, Maine)					FWS					X	
Radiobiological Investigation, Bureau of Commercial Fisheries, Beaufort, N.C.					FWS					X	
Atlantic Fishery Exploration and Gear Research Laboratory, Bureau of Commercial Fisheries, Coral Gables, Fla.					FWS					X	
Menhaden Investigation, Bureau of Commercial Fisheries, Beaufort, N.C.					FWS					X	
Institute of Fisheries Research, University of North Carolina, Morehead City, N.C.	X							X			
University of Delaware Marine Laboratory, Newark, Del.	X							X			
Laboratory of Radiation Biology, Fisheries Center, University of Washington, Seattle, Wash.				X				X			
Bermuda Biological Station, St. George's, Bermuda				X				X			
Oregon Fish Commission Research Laboratory, Astoria, Oreg.					State					X	
Duke University Marine Laboratory, Beaufort, N.C.	X							X			
Middle Atlantic investigation (Bureau of Commercial Fisheries, U.S. Fishery Laboratory), Beaufort, N.C.					FWS					X	
South Atlantic offshore fisheries investigation (Bureau of Commercial Fisheries), Brunswick, Ga.					FWS					X	
Hopkins Marine Station (Stanford University), Pacific Grove, Calif.		X						X			
Bingham Oceanographic Laboratory (Yale University), New Haven, Conn.	X							X			
Long Island Sound oyster investigation, Biological Laboratory (Bureau of Commercial Fisheries), Milford Conn.					FWS					X	
Maine Herring Exploration and Gear Research, Boothbay Harbor, Maine					FWS					X	
U.S. Fish and Wild Life Service clam investigation, Boothbay Harbor, Maine					FWS					X	

See footnotes at end of table, p. 63.

TABLE 3.—*List of oceanographic research laboratories according to type of organization*—Continued

Name[1]	Type of performance components: Educational-institutional laboratory	Educational-institutional research center	Nonprofit laboratory	Nonprofit research center	Government laboratory (parent organization)	Industrial laboratory	Type of organization, NASCO report: Large university laboratory	Small university laboratory	Large fisheries laboratory	Small fisheries laboratory	Navy
Friday Harbor Laboratory (University of Washington), Seattle	X							X			
Bureau of Commercial Fisheries, Stanford, Calif					FWS					X	
Department of Engineering (University of California), Berkeley, Calif	X							X			
Bears Bluff Laboratory, Wadmalaw Island, S.C					State					X	
Bureau of Commercial Fisheries, U.S. Shellfishery Laboratory, Gulf Breeze, Fla					FWS					X	
Gulf Coast Research Laboratory, Bureau of Commercial Fisheries, Ocean Springs, Miss					State					X	
State Fisheries Laboratory, Department of Conservation, New Brunswick, N.J					State					X	
Oregon State College, School of Science, Corvalis, Oreg	X							X			
Pacific Marine Station (College of the Pacific), Dillon Beach, Calif	X							X			
Walla Walla College, Biological Station, Anacortes, Wash	X							X			
Kerckhoff Marine Laboratory, Corona del Mar, Calif	X							X			
Naval Research Laboratory, Washington, D.C					USN						X
Hudson Laboratories, Dobbs Ferry, N.Y				X[4]							X
Navy Electronics Laboratory, San Diego, Calif					USN						X
U.S. Hydrographic Office, Washington, D.C					USN						X
Navy Mine Defense Laboratory (BuShips), Florida					USN						(5)
Applied Physics Laboratory (University of Washington), Seattle, Wash				X[4]							X
Naval Ordnance Laboratory, Silver Springs, Md					USN						(5)
Navy Radiological Defense Laboratory (BuShips), San Francisco					USN						(5)
U.S. Navy Underwater Sound Laboratory, New London, Conn					USN						(5)
David Taylor Model Basin, Washington, D.C					USN						(5)
Naval Ordnance Test Station, Inyokern, Calif					USN						(5)
Naval Air Material Center, Johnston, Pa					USN						(5)
U.S. Navy Civil Engineering Laboratory, Port Hueneme, Calif					USN						(5)

[1] Sequence of organizations is in decreasing order of expenditures, except for the naval laboratories listed last.
[2] An international organization with funds derived primarily from the United States through the State Department.
[3] International organizations deriving funds from the United States and Canada.
[4] Exclusively Navy supported.
[5] Not included in NASCO statistics.

Source: Unpublished data from NASCO questionnaire to oceanographic laboratories.

TABLE 4.—*List of oceanographic research activities according to program and scope of geographical activities*

Name	Program							Scope of geographical activity			
	Biological	Physical and chemical	Geological and geophysical	Acoustical	Miscellaneous	Military R. & D.	Survey	Worldwide deep water	Coastal	Local	No facility for field investigation
Scripps Institution of Oceanography, La Jolla, Calif.	X	X	X	X	X [1]	X	X	X	X	X	
Woods Hole Oceanographic Institute, Woods Hole, Mass.	X	X	X	X	X [2]	------	X [3]	X	X	X	
Lamont Geological Observatory, Palisades, N.Y.	X	X	X	X	X [1]	X	X	X	X	X	
Marine Laboratory, University of Miami, Virginia Key, Miami, Fla.	X	X	X	X	X [2]	X	------	------	X	X	
Pacific oceanic fishery investigation (Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service), Honolulu, Hawaii	X [4]	X	------	------	------	------	X	X	------	X	
Alaska Department of Fish and Game, Juneau, Alaska	X	------	------	------	------	------	------	------	------	X	
Department of Fish and Game, State of California, Sacramento, Calif.	X	------	------	------	------	------	------	------	X	------	
Department of Oceanography and Meteorology, Texas A. & M., College Station, Tex.	X	X	X	X	X [1 2]	------	------	X [5]	X	------	
Pacific salmon investigation (Bureau of Commercial Fisheries), Seattle, Wash.	X	------	------	------	------	------	------	X	------	------	
Bureau of Commercial Fisheries, Woods Hole, Mass.	X	------	------	------	------	------	------	X	X	------	
Department of Oceanography, University of Washington, Seattle, Wash.	X	X	X	------	------	------	------	X	X	X	
Gulf fishery investigation (Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service), Galveston, Tex.	X	------	------	------	------	------	------	------	X [6]	------	
Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, Calif.	X	X	------	------	------	------	------	X	X	------	
Chesapeake Bay Institute, Johns Hopkins University, Baltimore, Md.	X	X	------	------	------	------	------	------	------	X	
South Pacific fishery investigation, La Jolla, Calif.	X	------	------	------	------	------	------	X	------	------	
Arctic Research Laboratory, Fairbanks, Alaska	X	X	------	------	X [7]	------	------	------	X	------	
Fisheries Research Institute, University of Washington, College of Fisheries, Seattle, Wash.	X	------	------	------	------	------	------	X	------	------	
Marine Laboratory, Texas Game and Fish Commission, Rockport, Tex.	X	------	------	------	------	------	------	------	------	X	
Department of Meteorology and Oceanography, New York University, New York, N.Y.	------	X	------	X	X [8]	------	------	X	X	X	
North Atlantic Exploratory Fishing and Gear Research, Bureau of Commercial Fisheries, Boston, Mass.	X	------	------	------	------	------	X	X	------	------	
Hancock Foundation for Scientific Research, University of Southern California, Los Angeles, Calif.	X	X	X	X	------	------	------	------	X	------	
Virginia Fisheries Laboratory (College of William & Mary), Gloucester Point, Va.	X	------	------	------	------	------	------	------	------	X	

See footnotes at end of table, p. 67.

TABLE 4.—*List of oceanographic research activities according to program and scope of geographical activities*—Continued

Name	Program							Scope of geographical activity			
	Biological	Physical and chemical	Geological and geophysical	Acoustical	Miscellaneous	Military R. & D.	Survey	Worldwide deep water	Coastal	Local	No facility for field investigation
Pascagoula Fisheries Laboratory, Bureau of Commercial Fisheries, Pascagoula, Miss	X	------	------	------	------	------	X	------	X	------	
Narragansett Marine Laboratory (University of Rhode Island), Kingston, R.I	X	X	X	X	------	------	------	------	------	X	
Chesapeake shellfish investigation (Bureau of Commercial Fisheries), Annapolis, Md	X	------	------	------	------	------	------	------	------	X	
International Pacific Halibut Commission, University of Washington, Seattle, Wash	X	------	------	------	------	------	------	X	------	------	
Oceanographic Institute, Florida State University, Tallahassee, Fla	X	------	X	------	------	------	------	------	X	X	
Northern Pacific Exploratory Fishery and Gear Research, Seattle, Wash	X	------	------	------	------	------	X	X	------	------	
Institute of Marine Science, University of Texas, Port Aransas, Tex	X	------	X	------	------	------	------	------	------	X	
Hawaii Marine Laboratory (University of Hawaii), Honolulu, Hawaii	X	X	------	------	------	------	------	------	------	X	
Atlantic herring investigation (Bureau of Commercial Fisheries), Boothbay Harbor, Maine	X	------	------	------	------	------	------	X	------	X	
Radiobiological investigation (Bureau of Commercial Fisheries), Beaufort, N.C	X	------	------	------	X [9]	------	------	------	------	X	
Atlantic Fishery Exploration and Gear Research Laboratory, Bureau of Commercial Fisheries, Coral Gables, Fla	X	------	------	------	------	------	X	------	X	------	
Menhaden investigation (Bureau of Commercial Fisheries), Beaufort, N.C	X	------	------	------	------	------	------	------	X	X	
Institute of Fisheries Research, University of North Carolina, Morehead City, N.C	X	X	------	------	------	------	------	------	------	X	
University of Delaware Marine Laboratory, Newark, Del	X	------	------	------	------	------	------	------	------	X	
Laboratory of Radiation Biology, Fisheries Center, University of Washington, Seattle, Wash	X	------	------	------	X	------	------	------	------	------	X
Bermuda Biological Station, St. George's, Bermuda	X	------	------	------	X	------	------	------	------	X	
Oregon Fish Commission Research Laboratory, Astoria, Oreg	X	------	------	------	------	------	------	------	------	X	
Duke University Marine Laboratory, Beaufort, N.C	X	------	------	------	------	------	------	------	------	------	X
Middle Atlantic investigation, Bureau of Commercial Fisheries, U.S. Fishery Laboratory, Beaufort, N.C	X	------	------	------	------	------	X	X	------	------	
South Atlantic offshore fisheries investigation, Bureau of Commercial Fisheries, Brunswick, Ga	X	X	------	------	------	------	------	------	X	------	

See footnotes at end of table, p. 67.

TABLE 4.—*List of oceanographic research activities according to program and scope of geographical activities*—Continued

Name	Program							Scope of geographical activity			
	Biological	Physical and chemical	Geological and geophysical	Acoustical	Miscellaneous	Military R. & D.	Survey	Worldwide deep water	Coastal	Local	No facility for field investigation
Hopkins Marine Station (Stanford University), Pacific Grove, Calif.	X									X	
Bingham Oceanographic Laboratory (Yale University) New Haven, Conn.	X										X
Long Island Sound oyster investigation, Biological Laboratory (Bureau of Commercial Fisheries), Milford, Conn.	X									X	
Maine herring exploration and gear research, Boothbay Harbor, Maine	X						X		X		
U.S. Fish and Wildlife Service clam investigation, Boothbay Harbor, Maine	X									X	
Friday Harbor Laboratory (University of Washington) Seattle	X									X	
Bureau of Commercial Fisheries Stanford, Calif.	X										X
Department of Engineering (University of California), Berkeley, Calif.		X							X	X	
Bears Bluff Laboratory, Wadmalaw Island, S.C.	X									X	
Bureau of Commercial Fisheries, U.S. Shellfishery Laboratory, Gulf Breeze, Fla.	X									X	
Gulf Coast Research Laboratory Bureau of Commercial Fisheries, Ocean Springs, Miss.	X		X [10]							X	
State Fisheries Laboratory, Department of Conservation, New Brunswick, N.J.	X					X [11]				X	
Oregon State College, School of Science, Corvalis, Oreg.		X	X	X					X	X	
Pacific Marine Station (College of the Pacific), Dillon Beach, Calif.	X									X	
Walla Walla College Biological Station, Anacortes, Wash.	X									X	
Kerckhoff Marine Laboratory, Corona del Mar, Calif.	X									X	
Naval Research Laboratory, Washington, D.C.						X		X			
Hudson Laboratories, Dobbs Ferry, N.Y.		X	X	X		X		X	X		
Navy Electronics Laboratory, San Diego, Calif.		X	X	X		X		X	X		
U.S. Hydrographic Office, Washington, D.C.		X				X	X	X	X		
Navy Mine Defense Laboratory (BuShips), Florida			X			X			X	X	
Applied Physics Laboratory (University of Washington), Seattle, Wash.		X	X	X		X			X	X	
Naval Ordnance Laboratory, Silver Spring, Md.			X	X		X		X			
Navy Radiological Defense Laboratory (BuShips), San Francisco, Calif.	X	X				X					X
Applied Physics Laboratory (University of Washington), Seattle, Wash.		X		X						X	

See footnotes at end of table, p. 67.

TABLE 4.—*List of oceanographic research activities according to program and scope of geographical activities*—Continued

Name	Program							Scope of geographical activity			
	Biologica	Physical and chemical	Geological and geophysical	Acoustical	Miscellaneous	Military R. & D.	Survey	Worldwide deep water	Coastal	Local	No facility for field investigation
U.S. Navy Underwater Sound Laboratory, New London, Conn.						X		X			
David Taylor Model Basin, Washington, D.C.					[12]	X					X
Naval Ordnance Test Station, Inyokern, Calif.						X				X	
Naval Air Material Center, Johnstown, Pa.						X					X
U.S. Navy Civil Engineering Laboratory, Port Hueneme, Calif.						X				X	

1 Heavy use of radioactive techniques.
2 Meteorological.
3 Government funds also from BuShips, BuWeapons, and Air Force.
4 Applied research concerned with sea fishing studies, including the ecology, and thus with certain aspects of the physical and chemical environments. However, the research is focused on its relationship to biological content of the sea.
5 Coastal engineering.
6 Coastal in neritic province.
7 Structural and mechanical properties of sea ice.
8 Considerable emphasis on study of surface wave phenomenon.
9 Emphasis on accumulation of radioactive materials by fishery organisms and effect of accumulation on seafood resources.
10 Utilized for teaching by Louisiana State University.
11 Concerned with sport fishing.
12 Seakeeping of ships.

Source: Various data collected by author.

Any classification of these laboratories in finer detail would reveal a rich variety in programs, facilities and points of view. There is probably no typical oceanographic research organization. However, for the reader less familiar with this field, details of one—the Woods Hole Oceanographic Institution—are cited to add a necessary dimension to the previously mentioned list of statistics. These details have been extracted from a statement of Paul M. Fye, Director of Woods Hole.[45]

The Woods Hole Oceanographic Institution was founded in 1930 as a direct result of a recommendation of a National Academy of Sciences' Committee on Oceanography which had been studying the status of marine science in this country for 2½ years prior to the submission of its report in 1929. * * * It was chartered to prosecute the study of oceanography in all its branches—to maintain a laboratory or laboratories, together with boats and equipment, and a school for instruction in oceanography and allied subjects. We are a small research institution with a staff of 130 technically trained and approximately 300 regular employees. In the summertime our work is substantially increased by the addition of about 125 people who are generally faculty members of universities, graduate students, and college students. * * * Relatively few people are trained in our universities as oceanographers, but mostly we recruit people with training in fundamental disciplines such as chemistry, biology, physics, mathematics,

45 "Oceanography in the U.S." Hearings before the Special Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries, House of Representatives, Mar. 3—July 14, 1959, pp. 265–272.

geology and meteorology. At the present time our research staff has a composition as follows: Biologists, 29; Chemists, 13; Mathematicians, 7; Physicists, 19; Engineers, 26; Geologists, 14; Oceanographers, 16; Meteorologists, 10. From 1930 to 1958, 197 graduate students fellowships were granted, plus 123 postdoctoral and foreign fellowships. * * *

The original investment in shore facilities of $325,000 in 1930 was increased by $800,000 by the U.S. Navy in 1954. Scientific equipment valued at over one half million dollars is currently in use. * * * The composition of the WHOI fleet includes 4 deep sea vessels totalling 2940 tons. * * * [46]

This Institution was founded on the concept that science should be largely funded by private means and was provided with a private endowment of $2 million in addition to money for the land, the laboratory and the research vessel *Atlantis*. Today the market value of our endowment is estimated at 5 million dollars and there have been no substantial gifts for endowment since the first year. * * * Today, about 90 percent of our annual budget is obtained from Federal funds. * * * The budget for 1959 is shown in Table 5.

Flavor of some of the problems in operating oceanographic research laboratories has been brought out in the NASCO reports, particularly Chapter 12, concerned with marine sciences in the United States: [47]

Among the university-sponsored organizations, only the large ones have been able to maintain an extensive blue water operation and large departments in specialized categories such as physical oceanography and geochemistry. In order to support their large ships and technical staffs, most of these laboratories have found it necessary from time to time to conduct relatively large applied programs for the Government. In some cases such work has necessitated sacrificing more basic research projects. In others, the stimulation provided by applied problems has been helpful. However, laboratories should not have to undertake large applied projects primarily as a means of solving financial problems.

Each laboratory has its own particular problems, but some general patterns are discernible. The large laboratories with heavy Federal support need financial stability and predictability to rescue them from their present hand-to-mouth existence on short-term contracts. The insecurity of this existence is a constant worry to administration and staff alike; it interferes with long-range planning; and it sometimes results in taking on routine survey tasks that are not the proper work of a research organization and contribute little to the laboratory except as a financial stopgap. They desperately need ship replacements and additional shore facilities. They need the kind of institutional support that will permit them to maintain their salary scale at the current market value and provide reasonable stability to their operations.

The small laboratories also need ship and shore facilities but generally not so desperately. Often their chief material need is for modern scientific equipment. * * * However, their most pressing need is for growth and diversification of their staffs. The small laboratories consist almost exclusively of biologists and biological oceanographers. * * * The small laboratory has to grow in order to solve its problems effectively, and having done so, it finds a whole new set of problems waiting for it.

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[46] Further details are given of these ships in Table 8.
[47] NASCO Report, Chapter 12, op. cit., pp. 5–6.

TABLE 5.—*Budget for fiscal 1959, Woods Hole Oceanographic Institution—Breakdown showing sources of income and types of expenses*

	Thousands
Income:	
Government contracts:	
Navy	$2,722.4
National Science Foundation	623.2
Atomic Energy Commission	137.7
Air Force	59.7
Fish and Wildlife Service	40.0
Weather Bureau	15.0
Public Health Service	12.3
	3,610.3
Commonwealth of Massachusetts	20.0
Endowment	133.0
Associates	12.0
Total	3,775.3

[In thousands]

	Direct labor	Vessel operations	Supplies and equipment	Travel	Indirect costs	Total
Expenses:						
Biology	$105.5	$85.8	$21.7	$3.9	$54.2	$271.1
Chemistry	89.7	27.7	18.4	3.5	55.5	194.8
Geology	25.1	37.7	4.6	1.8	19.0	88.2
Geophysics	415.0	389.3	358.9	70.2	253.8	1,487.2
Meteorology	109.0		35.7	10.6	44.8	200.1
Physical oceanography	478.2	387.8	196.1	35.0	285.5	1,382.6
General		25.0	93.0	5.0	28.3	151.3
Total budget for year 1959	1,222.5	953.3	728.4	130.0	741.1	3,775.3
Percent	32	25	19	4	20	100
Actual costs, year 1958	$1,043.1	$593.3	$662.9	$132.7	$625.9	$3,057.9
Percent	34	19	22	4	21	100

Source: Hearings before the Special Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries, House of Representatives, 86th Cong., 1st sess., p. 270.

Many of the problems peculiar to oceanographic laboratories are revealed in Table 5. In the first instance it is clear that the funds from the original endowment for WHOI as a nonprofit institution now represent but a fraction of the total financial support; secondly, the U.S. Government strongly dominates the fiscal scene. Although a number of different agencies are represented, the Navy is the primary sponsor. What this tabulation fails to reveal is that a large part (some 30 percent) of the Navy support is for unspecified, basic research. Thus, the identity of the supporting organization is not necessarily an index of the type of activity expected. By and large, however, in an era of stringent research budgets, one might expect sponsors more likely to approve proposals for research if these proposals are in areas considered of highest priority by the particular Government agency, even if not considered of highest priority from the point of view of the investigator. In the view of Dr. Clifford C. Furnas, this is not necessarily harmful. In a recent appearance before the House Science and Astronautics Committee on June 3, 1960, Dr. Furnas entered a plea for "vectored," if not specifically directed, research to focus activity on those areas considered to be in the greatest interest to the national welfare, rather than to allow research investigators to follow random curiosity. The much broader and unanswered question is the level at which decisions are to be made as to *which* branches of science warrant special attention.

Another characteristic of the oceanographic laboratory revealed in Table 5 is the relatively large proportion of funds that must be allo-

cated to vessel operation, supplies, and equipment. In this case, the vessels themselves are of such age or are made available under such terms that no amortization costs are included. When accounting for funds, however, particularly in terms of new ships; this element of capital expenditures and operating cost, regardless of how ultimately defrayed, represents a large proportion of the total for research. In this regard, oceanic research resembles research in outer space.

Additional details are given in Table 6 on sizes of these various research laboratories, in terms of budgets and staff.

TABLE 6.—*Budget and staff breakdown by performance component*

	Large university	Small university	Large fishery	Small fishery	Navy unit	Total
Number of laboratories	6	19	6	24	5	60
Total budget	$10, 165, 000	$2, 430, 000	$3, 339, 000	$2, 884, 000	[1] $4, 808, 000	$23, 626, 000
Average budget	$1, 700, 000	$128, 000	$556, 000	$120, 000	$960, 000	$394, 000
Total staff	1, 250	285	298	314	517	2, 664
Ph. D.'s	219	79	35	49	47	429
Master's	105	45	57	71	77	355
Bachelor's or equivalent	274	104	109	78	199	764
Scientific staff	598	228	201	198	323	1, 548
Supporting staff	652	57	97	116	194	1, 116
Ratio: Ph. D./total	1:5. 7	1:3. 6	1:8. 5	1:6. 4	1:11. 0	1:6. 2
Ratio: Ph. D./scientific staff	1:2. 7	1:2. 9	1:5. 7	1:4. 0	1:6. 8	1:3. 6
Annual budget/scientific staff member	$17, 000	$11, 000	$16, 000	$15, 000	$15, 000	$15, 000

[1] Does not include ship operating costs.

Source: NASCO Report, Ch. 12, Table 3.

B. MANPOWER

Perhaps the most striking characteristic of the field of oceanographic research considering its significance to the military, political and economic well-being of the Nation is the relatively small number of individuals who are occupationally identified with marine sciences. Totals are given in Table 6. According to the NASCO reports, in 1958 there were only 1,548 scientists plus 1,116 supporting staff so engaged. Only about 560 of the scientists are regarded as having independent responsibilities at project leader level. This tabulation does not include either scientists or supporting staff who are undertaking hydrographic surveying for the U.S. Coast and Geodetic Survey; scientists and supporting staff engaged in military oceanography, either in naval or nonnaval laboratories; or those engaged in operating ships which are currently engaged predominantly in military activities. The supporting staffs, however, do include technicians, clerical and administrative personnel and ship operating force.

An additional breakdown, according to level of education—Ph. D.'s, Masters, or Bachelor degrees—is also given in Table 6. Because the capabilities of an organization to undertake research are often expressed in the proportion of Ph.D. to non-Ph. D. scientists, these ratios have been included. The ratio across the board of 1,548 participants is 1 to 3.6; for senior investigators, it is estimated as closer to 1 to 1.7.

Since any interpretation depends heavily on comparisons with other fields, similar inventories outside of oceanography have been sought, although such data are hard to come by. Fragmentary data

are given in Table 7, indicating that the Ph. D. content of oceanographic staff is unusually rich.

The tabulation of Ph. D. ratio by large and small universities, fisheries or Naval units, is most significant in revealing the relatively fewer number of Ph. D.'s in Naval organizations. This is generally consistent with well recognized contemporary problems in staffing Government-owned and operated laboratories.

TABLE 7a.—*Ratio of doctorates to all degrees in various broad fields of research*[1]

Field	Number of Ph. D.'s	Total all degrees	Ratio
Private industry:			
Chemical and allied	2,572	12,154	1: 4.3
Petroleum	986	4,097	1: 4.1
Instruments	69	2,904	1:42.08
Aeronautical	270	16,340	1:60.5
Machinery and equipment	45	2,162	1:48.04
Electronics and electrical	1,170	24,392	1:20.8
Rubber	243	1,719	1: 7.07
Food	218	1,148	1: 5.2
Biological and pharmaceutical	1,041	2,946	1: 2.8
Automotive	36	306	1: 8.5
Steel	24	244	1:10.16
Other private industry	1,497	10,617	1: 7.09
Research institutes	1,266	5,717	1: 4.5
Private consultants	251	1,887	1: 7.4
AEC contractors	1,951	9,170	1: 4.7
Government laboratories	1,994	20,357	1:10.2

[1] This tabulation includes both junior and senior research personnel.

Source: "1959 National Survey of Professional Scientific Salaries," Los Alamos Scientific Laboratory of the University of California, Los Alamos, N. Mex., p. 18.

TABLE 7b.—*Ratio of doctorates to all degrees for senior investigators in various fields of science*[1]

Field	Number of M.D.'s and Ph. D.'s	Total all degrees	Ratio
Agricultural sciences	2,211	9,429	1: 4.2
Biological sciences	11,912	17,562	1: 1.4
Medical sciences	1,693	1,834	1: 1.08
Psychology	6,548	10,919	1: 1.6
Earth sciences	1,932	12,646	1: 6.5
Meteorology	162	1,987	1:12.2
Mathematics	3,126	9,816	1: 3.1
Astronomy	237	352	1: 1.4
Physics	6,138	12,400	1: 2.02
Chemistry	13,989	34,697	1: 2.4
Chemical engineering	918	4,750	1: 5.1
Sanitary engineering	133	3,279	1:24.6
All other engineering	1,316	12,619	1: 9.5
All other specialties	1,203	3,583	1: 2.8

[1] This tabulation includes only senior personnel.

Source: "Scientific Manpower Bulletin" NSF 60-22, April 1960, No. 11, p. 3.

Table 6 further includes the annual research budget per scientific staff member. The average of $15,000 per man for Fiscal 1958 seems somewhat lower than figures of $20,000 to $22,000 per man informally quoted by research administrators as a typical operating cost. The fact that oceanographers "cost less" per man to support, if indeed this is the case, is all the more striking because, as is brought out subsequently, facilities represent a significant cost element in terms of initial cost and amortization and ship operating costs. This anomaly can only be resolved by further study of the salaries of those engaged

in oceanic research and the overhead operations as compared to other fields of science, and such data were not readily available.

While on the question of manpower, this report notes that virtually all participants in oceanic research claim the shortage of manpower as one of the two most crushing problems—a shortage which is considered to inhibit growth. One proposed solution, discussed at length subsequently, lies in an increase in students and in educational training facilities. Some comment on the present status of educational facilities is thus pertinent. In a recent appearance before the House Science and Astronautics Committee, Secretary James Wakelin contributed a list of institutions now engaged in training in the marine sciences:

Columbia University.
Johns Hopkins University.
Oregon State College.
Texas A. & M. College.
University of Miami.
University of Rhode Island.
University of Southern California.
University of Michigan.
Scripps Institution of Oceanography.
Woods Hole Oceanographic Institution.[48]

To this list might be added the University of Washington, Harvard, Massachusetts Institute of Technology, Yale, New York University, Florida State, and University of Hawaii.

Additional data on the trend for the past 3 years indicates an encouraging growth both of faculty and of graduate students:

> The most critical elements in expanding our effort in this field is the shortage of scientific personnel to man the ships and carry out a creative program. Recently, we have compiled data from 10 major universities and institutions concerned with training of oceanographers as well as the conduct of research. This information is most encouraging and we must do everything possible to continue the trend. The number of professional oceanographers at the Ph. D., M.S., or equivalent level and the number of their graduate students for the past 3 years is summarized in the following table. These data show that there has been an increase of 28 percent in the professional level and of 80 percent in graduate students over the last 3 years: [49]

	1958	1959	1960
Professor level (Ph. D., M.S., or equivalent)	253	290	327
Graduate students	137	176	246

At this same hearing, questions were raised concerning the training of midshipmen and merchant seamen in the area of oceanography and in reply, the following information was provided:

> Mr. VAN PELT. Mr. Secretary, do any of our national academies—have * * * a program covering the subject which you were discussing this morning? I am thinking of Annapolis or the Merchant Marine Academy. * * *
>
> Dr. WAKELIN. * * * I don't believe so, for this reason: That oceanography is a composite of a number of basic disciplines, such as physics and chemistry and biology and geology. The training that has gone on in the Government-supported institutions at the undergraduate level is predominantly in the basic sciences as primary disciplines.
>
> There are training programs at the University of California, at Scripps, which take not only high school and college students on a summer basis, but also go on

[48] "Frontiers in Oceanic Research," op. cit., p. 49.
[49] Ibid., p. 45.

to give the master's degree in oceanography. They all combine a whole group of studies in the basic sciences under the one subject cover of oceanography.

I am not aware of an oceanography—any oceanographic part of the curriculum at the U.S. Naval Postgraduate School, for example, which I think would be the first place in the Navy where we would address ourselves to oceanography because then the undergraduates of the Academy would have had the proper training in the basic sciences, so they could broaden themselves into oceanography. * * * The U.S. Naval Academy offers two elective courses for academically qualified midshipmen:

Oceanography: 14 midshipmen enrolled.

Underwater acoustics: Eight midshipmen enrolled.

Postgraduate training is sponsored by the Navy as follows:

Oceanography at University of Washington (2-year course): one officer per year now, to be increased to five officers per year in September 1960.

Hydrography (geodesy) at the Ohio State University (2-year course): three officers per year.

Meteorology at U.S. Naval Postgraduate School offers basic course in oceanography related to meteorology: 35 officers per year.[50]

In other testimony by Vice Adm. A. C. Richmond, Commandant, U.S. Coast Guard, it was noted that no courses, either required or elective, are offered at the Coast Guard Academy at New London. However, it is Coast Guard practice to assign graduate students, every 2 or 3 years, for study in this field, and over the past 20 years a total of 16 were so trained at various institutions.[51]

At the Merchant Marine Academy at Kings Point, N.Y., there is apparently also no required or elective course in oceanography. The only aspect which these graduates encounter deals with hydrodynamics of ships in a seaway.[52] Some courses in ocean meteorology are offered as electives at the U.S. Navy Post Graduate School in Monterey, Calif.

From this background, it is apparent that a number of educational institutions in the United States have a rather broad program in the marine sciences in contrast to virtually no offerings in the Naval Academy, Coast Guard Academy and Merchant Marine Academy—the three educational institutions operated by the Federal Government specifically devoted to matters concerned with the sea. Implications with regard to broadening the programs in these Government schools are discussed subsequently.

Further details on the fields of specialization represented by those now conducting oceanographic research would provide one additional, significant dimension of the manpower problem. These data, however, do not appear available. From reference to the composition of the staff at Woods Hole, it is noted that a number of disciplines are included; graduates in oceanography represent roughly 12 percent of the total doing research. This situation is apparently not derived simply from want of such specialists; so much of what collectively is termed marine science derives its fundamentals from physics, chemistry, biology, and geology, that except for descriptive aspects of oceanography, graduates and those with experience in other fields have and will continue to make substantial contributions. This multidisciplinary character of oceanic research has numerous implications regarding sources of manpower discussed subsequently.

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[50] "Frontiers in Oceanic Research," op. cit., pp. 61–62.
[51] "Oceanography in the U.S.," op. cit., pp. 68–69.
[52] Ibid, p. 78.

C. FACILITIES

1. Ships

It is self-evident that oceanographic research, like geology, cannot be conducted to any appreciable extent within a laboratory. *The sea, its contents, its bottom, and the relationships which form the environment for marine life require the presence of research staff in and on the oceans to observe, to sample, and to interpret results and subtle interrelationships on the spot. Research at sea requires ships.*

Research vessels may be classified according to four basic missions:

1. *Basic research*—for any of the types of investigations mentioned in Section V.

2. *Survey ships*—to map the oceans, the bottom topography, the coastlines, currents, temperature, and other characteristics of the water.

3. *Resources and fisheries ships*—to observe fish behavior; to catch fish, store and process them; to experiment with new types of fishing techniques and equipment; and, regarding mineral resources, to sample the ocean floor.

4. *Ships for military research and development*—to test and evaluate new devices and techniques particularly in programs concerned with underwater acoustics, frequently in concert with other elements of the fleet.

5. *Small vessels*—for coastal and inshore operations—generally less than 100 feet long, and displacing less than 100 tons.

The present U.S. fleet of oceanographic research vessels, capable of operating away from purely coastal areas, numbers 50 ships, which in the aggregate displace 79,446 long tons (2,240 pounds). These have been listed according to the first four categories in Table 8.

New oceanographic research ships, already funded, are listed in Table 9.

At this point, an apparent inconsistency bears explanation. Earlier, it was stated that the NASCO and other programs excluded military oceanography because of the defense application and military security aspects which characterize that activity. Yet, both in the inventory of existing ships and, as is seen later, in plans for new construction, those vessels initially earmarked for military oceanography have been included. There are two reasons: in the first instance, any ships which are specifically designed for oceanographic research have sufficient versatility that, even though planned for initial use in military oceanography, they could be used for more basic research. Secondly, and even more important, ships for military oceanography more often than not must compete for construction funds with ships projected for oceanographic research generally. Especially since future budgets will apparently reflect abnormally large proportions for new construction, the complex of elements considered at this time as part of a long-range program should include all major costs such as of new ships, even those to be employed in military operations. On the other hand, funds for military oceanography itself are far more readily available through transfer from particular military requirements, entailing development of hardware; they are thus more likely to be adequately provided for than any similar funds for the construction of new ships to do the research.

TABLE 8.—*Oceanographic ships*

A. SEAGOING RESEARCH SHIPS

Name	Displacement tonnage (long tons)	Length (feet)	Year placed in commission [2]	Operated by—
1. Atlantis [1]	300	142	1931	Woods Hole Oceanographic Institution.
2. Crawford	280	125	1927	Do.
3. Bear [1]	260	100	1943	Do.
4. Chain	2,100	214	1943	Do.
5. Vema [1]	533	202	1923	Lamont Geological Observatory.
6. Hidalgo	240	136	1944	Texas A. & M. College.
7. Spencer F. Baird	505	143	1944	Scripps Institution of Oceanography.
8. Horizon [1]	505	143	1944	Do.
9. Orca	200	100	1926	Do.
10. Stranger	300	134	1938	Do.
11. Brown Bear [1]	270	114	1934	University of Washington.
12. Velero IV [2]	292	110	1934	University of Southern California.
13. Paolina T [2]	111	80	1948	Scripps Institution of Oceanography.
14. Gerda [2]	75	75	1944	University of Miami.
15. Argo (Snatch)	2,100	310	1943	Scripps Institution of Oceanography.
Total	8,071			

B. MILITARY RESEARCH AND DEVELOPMENT SHIPS

Name	Displacement tonnage (long tons)	Length (feet)	Year placed in commission [2]	Operated by—
1. Gibbs [1]	2,700	310	1942	Hudson Laboratory.
2. Allegheny-ATA [1]	760	146	1945	Do.
3. EPCE(RP) 856 [1]	818	184	1944	Underwater Sound Laboratory.
4. Grouper [1]	1,500	308	1942	50 percent, Underwater Sound Laboratory. 50 percent, Naval Research Laboratory.
5. Rockville [1]	800	180	1944	Naval Research Laboratory.
6. Somersworth [1]	800	185	1944	Do.
7. Hunting [1]	800	200	1945	Do.
8. Yamacraw (ARC-5)	1,000	109	1945	Bell Telephone Laboratories.
9. EPCE(R) 857 [1]	818	184	1944	Navy Electronics Laboratory.
10. Baya (submarine) [2]	1,500		1944	
Total	11,496			

C. OCEANOGRAPHIC SURVEY SHIPS

Name	Displacement tonnage (long tons)	Length (feet)	Year placed in commission [2]	Operated by—
1. Pioneer [1]	2,600	312	1943	Coast and Geodetic Survey.
2. Pathfinder	2,600	229	1942	Do.
3. Explorer	1,900	220	1940	Do.
4. Hydrographer [1]	1,106	164	1931	Do.
5. Hodgson [1]	267	136	1943	Do.
6. Bowie [1]	267	136	1943	Do.
7. Patton	150	88	1941	Do.
8. Marmer	150	101		Do.
9. Lester Jones	150	88	1940	Do.
10. Cowie	128	103	1926	Do.
11. Gilbert	95	78	1952	Do.
12. Surveyor	3,070	293	1959	Do.
13. San Pablo [1]	2,700	310	1943	Hydrographic Office.
14. Rehoboth [1]	2,700	310	1944	Do.
15. Dutton T-AGS [1 3]	13,000	455	1944	Bureau of Ordnance.
16. Bowditch T-AGS [1 3]	13,000	455	1944	Do.
17. Michelson T-AGS [1 3]	13,000	455	1944	Do.
18. Evergreen	1,025	180	1943	U.S. Coast Guard.
Total	57,308			

See footnotes at end of table, p. 76.

TABLE 8.—*Oceanographic ships*—Continued

D. RESOURCES AND FISHERIES SHIPS

Name	Displacement tonnage (long tons)	Length (feet)	Year placed in commission [2]	Operated by—
1. Oregon [1]	254	100		Bureau of Commercial Fisheries, Pascagoula Laboratory.
2. Silver Bay [1]	239	96		Do.
3. Hugh M. Smith [1]	392	128	1945	Bureau of Commercial Fisheries, Pacific Oceanic Fishery Investigation Laboratory.
4. Charles H. Gilbert [1]	196	122	1952	Do.
5. Black Douglas [1]	370	150	1930	Bureau of Commercial Fisheries, Biological Laboratory, Pacific Fishery Investigation.
6. Alaska [1]	240	100	1947	California State Department of Fish and Game.
7. John N. Cobb [1]	240	100		Bureau of Commercial Fisheries, North Pacific Fisheries Exploration.
Total	1,931			

[1] To be replaced within 10 years.
[2] Source: Information furnished by Office of Naval Research and Navy Office of Legislative Affairs; all other items extracted from NASCO report, Ch. 6, table 8.
[3] In service by end of 1959.

TABLE 9.—*New oceanographic ships, currently funded*

Name	Tonnage	Length	Sponsor	Operating agency
1. [1]	1,000		NSF	Woods Hole Oceanographic Institution.
2. AGOR-3 [2]	1,370	207	Bureau of Ships	Lamont Geological Observatory.
3.		80	ONR	Oregon State University.

[1] Contract for design placed with Bethlehem Shipbuilding Co., Quincy, Mass.
[2] Contract placed May 26, 1960, with Gibbs Shipbuilding Corp., Jacksonville, Fla., for $2,875,975.

Source: U.S. Navy.

Two elements of oceanographic research related to ships themselves bear special mention—the relatively large capital costs of facilities to conduct oceanographic research and the present state of the U.S. fleet in terms of obsolescence and the heavy use of converted hulls.

Oceanography, like a number of contemporary scientific fields such as research in outer space, requires an unusually massive investment in facilities. Amortization of capital expenditures and operating costs may equal or even exceed direct expenses associated with the conduct of research itself. As a matter of fact, projected plans for U.S. oceanographic research for the next 10 years include exceedingly heavy demands of funds for new ships. The question might easily be raised as to whether the present fleet is inadequate. Table 8 reveals that, except for C. & G. S. *Surveyor*, virtually all of the ships now engaged in oceanographic research were constructed prior to 1945 and the average age of these vessels is 18 years. By almost any standards, many of these ships are now or soon will be overage. Only one of the entire fleet was specifically designed for oceanographic research.

Thus this fleet is characterized by being not only old but made up primarily of conversions. Whether they can effectively serve a function different from that intended can best be judged from a set of basic requirements evolved by those professionally associated with the

field; a summation of the subject by Dr. Columbus O'D. Iselin has been extracted as follows to illuminate this problem further:

There are certain aspects of oceanography that are essentially independent of time. For example, most problems in submarine geology can be taken up next year or the year after. There are other important questions that are strongly time dependent. Often the problem involves seasonal variations. Less frequently, it is a question of comparing data gained at the same season and place one year after the other.

In planning his field investigations, the oceanographer is continually beset by questions of timing and weather. It is usually unprofitable to send a ship North in the winter months, for the number of reasonably calm days on a given cruise may be so few that almost nothing new is discovered. In winter, beyond the limits of loran reception, even navigation may be hopelessly uncertain in stormy weather. It becomes impossible to carry out effective field observations in the research vessel available today as the wind increases beyond about Force 5 (17–21 knots). Thus for the most part, the ocean can only be adequately described for the calmer seasons and for the calmer latitudes.

Even in low latitudes, prevalent tropical storms at certain seasons have resulted in big gaps in our knowledge concerning seasonal changes. For the most part, what can be done by dodging the bad weather has by now been done. A major need in the marine sciences today is to round out both the picture of seasonal changes and to secure observations, for example, acoustical observations, during the progress of a storm.

Undoubtedly, the chief limitation of the vessels today is their inability to make scientific observations except in relatively moderate weather, and therefore a primary objective of this study is to develop superior sea-keeping vessels within reasonable limitations of size, first cost and operating expense, *and to thus make all weather oceanography possible.*

As above stated, the prime requirement of a research ship is seaworthiness. Not only must every gale be rode out successfully, but the observational program must continue for as long as possible before heaving to, and when hove to, the ship must be able to maintain her position so that precious time is not lost in regaining her station. In this respect the interest of the oceanographer corresponds exactly with that of the fisherman. In both cases, *it is the maximum number of working days in a selected area that counts*, rather than a round voyage at minimum expense, which is the prime objective of merchant ships. For fishing and for science, the cost of fuel is a secondary consideration, compared with the ability to continue with the work at hand. If advisable, the merchant ship can lengthen the course in order to avoid storms, but the oceanographer does not want to have to give way to the weather. That he has had to do so in the past is very evident, when one observes the distribution of oceanographic stations; in the winter months there are few data from high latitudes. We know almost nothing about the Gulf Stream between the months of November and April, for example. In winter, the oceanographic vessel usually heads South, because only in that way can the number of working days per voyage be kept at a favorable level.

Some aspects of seaworthiness can, of course, be gained by increasing the size of the vessel. However, even if expense were no consideration, the oceanographer prefers a not too large ship. As in fishing, the height of the working deck above the water should be kept as small as is consistent with reasonably dry decks, since the safe handling of instruments and nets in and out of the water is a prime consideration. Furthermore, both operations are carried out while stopped and with the sea abeam, during which time it becomes most desirable to reduce leeway; a deep draft and a well balanced above water profile are therefore important design features.[53]

Further details concerning the design of modern oceanographic research ships that can be used as a criterion when evaluating the adequacy of the current fleet were presented by Lester Rosenblatt to the Society of Naval Architects and Marine Engineers, May 26–28, 1960, significant portions of which have been extracted as follows:

Current requirements of oceanographic research are such that a vessel must be capable of providing a satisfactory working platform at sea state 5 minimum

[53] "Report on a Pre-design Engineering Study of the Development of Superior Ships for Oceanographic Research," by Francis Minot, Woods Hole Oceanographic Institution, Ref. No. 58-26, 1953.

and preferably at sea state 6. It is, therefore, obvious that in order to attain the degree of seakeeping ability required by the oceanographer, it will be necessary not only to make a judicious choice of dimensions and hull form, but also to provide additional means of controlling ship motions within the limits acceptable for satisfactory performance of work. The consensus of oceanographers on this matter is that even a 5 percent loss of space, a comparable loss of deadweight, and an increased cost in the same magnitude are a reasonable price to pay for increasing the ship's seakeeping ability sufficiently to permit operation in the next higher sea state.

High degrees of maneuverability and directional stability, i.e., course keeping ability, are also essential requirements of an oceanographic research ship. The nature of oceanographic research makes it necessary that for certain observations and measurements the ship be brought on an exact heading and be maintained at such heading, frequently at zero speed. This is definitely a difficult maneuver in the higher sea states contemplated by the oceanographers. Directional stability is important not only in holding the desired heading once it is attained, but also in maintaining course while proceeding from station to station, especially in relatively severe weather and on headings adversely affected by wind direction.

Ability to heave to and to maintain position during heavy weather in the general neighborhood of the observation area is also essential for a research ship. This ability is of great value because it saves the time which would otherwise be required to regain position at the end of bad weather, and it affords rest and comfort to the personnel during the period of idleness enforced by bad weather.

Reliability of a higher degree than for normal ship practice is another basic requirement which must be attained in research ships. They sail the loneliest and least traveled reaches of the ocean and, of necessity, are often remote from any port for long periods. Therefore, for efficiency of scientific effort, it is of utmost importance that breakdowns in machinery and equipment be avoided to the maximum extent possible, and, in case of breakdown, that the ship have the ability to make port on her own resources.

In addition to the foregoing basic requirements a successful oceanographic research ship must have adequate range at reasonable speeds to reach the remotest areas of the oceans and be able to stay there a sufficient time to perform her assigned task. This generally requires a range at cruising speed of well over 6,000 miles. Furthermore, the oceanographic research ship must have ample reserve power and reserve fuel capacity to operate effectively in the sea states required by modern oceanographic research.

Since sound is rapidly becoming one of the principal tools used in oceanography, quietness and effective noise control are basic requirements of research vessels. The advantages of a ship which radiates a minimum of noise into the water cannot be overemphasized. Devices operating over a very wide range of frequencies are commonly employed on research ships. Therefore, to obtain an acoustically satisfactory vessel, it is of utmost importance to eliminate or, if that is not possible, to quiet every potential source of noise.[54]

It is thus apparent that the hull form, mechanical plant, and systems of ship control should provide a stable platform in the worst kind of weather. Oceanographers claim that these objectives cannot be met with converted ships whose hull design might well reflect other demands originally for bulk cargo, high speed, or for weapons.

Perhaps another criterion of the effectiveness or lack thereof of particular ships to fulfill their intended function for research is the ratio between the number of crew to the number in the scientific party. Quite obviously, the smaller is this number the lower is the operating cost and the higher is the proportion of space on board devoted to laboratory and research functions, rather than to servicing of the vehicle itself which should be incidental to every extent possible to the tasks at hand.

An optimum ratio of 1 to 1 has been cited as a criterion for design. Most of the existing ships have a ratio of crew to scientists of 3 to 1, up to 10 to 1. The consequences of this excessive size of required crew are readily apparent.

[54] "The Design of Modern Oceanographic Research Ships," by Lester Rosenblatt, paper presented to The Society of Naval Architects and Marine Engineers, May 26-28, 1960, pp. 4-5.

2. *Deep Ocean Probes—Bathyscaph "Trieste," "Aluminaut," and Other Vehicles for Exploration of the Deep Sea*

While present knowledge of the sea is scanty, that concerning detail of the ocean bottom and of activities in deep water is even more seriously deficient. Most exploration has taken place on or near the surface of the sea or in shallow water at the boundaries—partly because these regions have been in the past the most significant, partly because these regions have been the only ones readily accessible.

To study the whole complex—the composition of the bottom, the vertical as well as horizontal circulation of currents, the various layers of biological activities—it is necessary that the scientists literally probe deeply. Some such research has already been successfully conducted through various instruments dangled by lines from surface ships, dragged on the bottom or telemetered to receiving stations from free-floating buoys set to drift at specific depths.

In all of these cases, the scientist has been remote from the subject of study, a separation not considered satisfactory by oceanographers:

> The scientist uses his senses in combination with his understanding and intuition to unravel the character of the world around him. He wants to see, touch, taste, smell, and hear the universe. To do this requires refinement and extension of these senses in space, precision, and discrimination. He uses instruments and tools as extensions of his senses and himself. Our modern civilization has provided a broad technology for these purposes and we believe that marine science should use much more of this modern technology. * * * For a wide variety of exploratory and experimental problems the investigator would like ideally to go down to the sea floor, walk around, observe, and collect specimens, and see to what extent the environment on or near the bottom of the sea is like that on the surface of the land. The scientist would like also to be able to use as many of his land learned techniques as possible. Existing bathyscaphs provide a first approach to this ideal and greatly improved submersibles are now technically and economically feasible. These improved deep submersibles are needed to complement the limited research capabilities of surface ships.[55]

Manned deep-diving vehicles thus appear required to complete the set of facilities to undertake a complete program of oceanic research.

The bathyscaph *Trieste,* now owned and operated by the U.S. Navy, represents one of the two similar devices in which man may descend to almost any depth to observe the environment and natural phenomenon of the entire water column, to make multiple and continuous measurements under immediate control of the scientist himself, and to selectively sample what he observes. The bathyscaph was invented by Auguste Piccard and consists, essentially, of an underwater blimp. Its cabin, which ordinarily holds two passengers, is a sphere of high-strength steel 6 feet 7 inches in diameter and 3.54 inches thick. Because of the thickness of walls to provide strength against hydrostatic pressure, the gondola is too heavy to float alone. It is thus suspended from a metal flotation tank roughly 50-feet long and 11 feet 6 inches in diameter and containing gasoline. This tank thus provides the supplementary buoyancy that permits controlled descent and ascent of the entire gondola-tank vehicle. Ten tons of iron pellets are carried as ballast.

The gondola is fitted with two viewing ports of plexiglass through which visual observations may be made continuously. Natural sunlight, which fades and disappears at depths on the order of 1,000 feet, is supplemented by an externally mounted, electrically powered mercury lamp.

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[55] Oceanography, 1960-70, Engineering Needs for Ocean Exploration," NASCO Report, ch. 7, pp. 1-2.

In recognition of these unique characteristics, the U.S. Navy sponsored a series of 26 dives with the craft in the Mediterranean Sea in the summer of 1957 and a wide variety of useful observations were made, including underwater sound intensity, behavior of fish, eels and marine worms, temperature and salinity of the sea, and the general geological terrain of the ocean bottom.[57]

Subsequently, in 1958, the *Trieste* was purchased by the U.S. Navy and delivered to the Naval Electronics Laboratory at San Diego for operation. It was then prepared for Project Nekton—a research operation involving modification of the *Trieste*, particularly through the use of a stronger sphere, for descent to the deepest known area—the Challenger Deep near Guam.

Although earlier descents had been made in manned vehicles, particularly the sphere of Beebe-Barton,[56] and the French FRNS–3, the near sister ship to the *Trieste*, the U.S. bathyscaph represents the *only* currently operating vehicle that permits *unlimited* descent for purposes of scientific observation.

The epic-making dive on January 23, 1960, has been described to the House Committee on Science and Astronautics by Dr. Andreas B. Rechnitzer, who was chief scientist for the Project Nekton:

> The U.S. Navy bathyscaph *Trieste* successfully penetrated to the deepest known location in the oceans on January 23, 1960. Carrying two men 7 miles below the ocean's surface this scientific breakthrough has opened all of the ocean waters to exploration and exploitation. In the execution of this feat and the preliminary dives leading up to achieving the ultimate in deep dives (70 in total for the *Trieste*) the bathyscaph program has yielded scientific and technical information of major importance to future manned exploration of the oceans.
>
> The Honorable George P. Miller, member of this committee, recognized the importance of this dive and acknowledged the feat by an entry in the Appendix of the Congressional Record published February 3, 1960. The item was entitled "Oceanography: Jules Verne 1960." Herein he acknowledged the relatively unheralded accomplishment of the U.S. Project Nekton that included in its program the deepest known possible descent by man; that is, to the bottom of the Challenger Deep (35,800 feet).
>
> The 5-hour descent permitted adequate time for observations of the environmental conditions characteristic of the 7-mile column of water. On the sea floor, 35,800 feet down in the Challenger Deep, the occupants of the sphere viewed living organisms, observed the physical characteristics of the sea floor and conveyed to the surface by voice via an electronic acoustic device that they were safely at the bottom. The deep dive stands by itself as a significant achievement by man in his unending attempt to expand his capabilities to occupy and investigate more of the Earth's spaces. The record descents made during Project Nekton (18,600 feet, 24,000 and 35,800 feet) are in reality only a byproduct of a scientific program seeking information of diverse types. Technologically it does represent a significant milestone which will undoubtedly incite future development in deep submersibles and equipment for manned and unmanned exploration and exploitation of "inner space." The development of a vehicle with the capabilities of the *Trieste*, makes a greater part of the oceans' 1,370 million cubic kilometers of water available as an operating medium for national security. It also renders much of the 361 million square kilometers of sea floor accessible for the search of minerals, fuels, and other natural resources. Prior to any significant utilization of this geographic frontier there is a requirement for the development of basic knowledge above the deep sea environment and the operational problems that are to be encountered. This bathyscaph program and the era of undersea operation is now in effect, but it obviously involves only a modest nucleus of equipment and personnel. The bathyscaph, as purchased by the United States, is in reality a model "T" of the deep submersibles. It has, however, conquered the depth barrier and points the way to more advanced vehicles. Nevertheless, as far as

[56] 4,488 feet, in October 1948.
[57] "The Bathyscaph," by Dietz, Lewis, and Rechnitzer, *Scientific American*, April 1958, pp. 27–33.

we know, it is still the best in the world. *French and Russian bathyscaphs under development will undoubtedly surpass the versatility of the "Trieste."* [58] [Emphasis added.]

Further important comments on the *Trieste* follow:

Although the bathyscaph has the capability of operating to any depth in the oceans it cannot be safely operated in rough seas and *is limited to near shore operations due to a lack of adequate mother-ship facilities. Therefore, the present scope of operation of the craft is seriously curtailed as deep ocean areas are not usually located close to major shore base facilities.* [Emphasis added.] The average depths of the oceans is approximately 2 miles. To reach this depth from San Diego requires, at least, a 120-mile tow. The craft is necessarily constructed to be as light as possible. Therefore, it is structurally weak against surface waves and swell.

Many important military projects under study involve deepwater investigations. Such studies could be markedly advanced if the capabilities of the bathyscaph could be employed. Unfortunately the limitations imposed by ocean surface conditions and the cumbersome towing that is involved in moving the craft to the diving location renders the craft limited to near shore operations at present. Remote locations such as Hawaii and Guam are satisfactory insofar as shore based logistic support is concerned. But again the diving operation must be limited to a radius of approximatly 200 miles from port before a mother ship is available.

It has been planned, since the purchase of the *Trieste,* that the craft would be made available to scientists of the United States. Many of these individuals have special problems that require dives to be made in other areas than San Diego or Guam. Ideally the craft should be transported to the desired location wherever it might be operated. To do this effectively an oceanographic research ship capable of servicing the craft would be very necessary in such an operation and would serve as a mobile base for applied oceanography.

The National Academy of Sciences, "National Research Council Committee on Oceanography Report No. 7, 1959," envisages the development of a variety of manned and unmanned submersibles and cites the need for such craft in an expanded oceanographic research program. Already the commercially designed 15,000-foot *Aluminaut* (Reynolds Aluminum Co.) is well advanced. Several deep submersibles are being designed by other organizations in the United States. None are in the construction stages.[59]

It is thus clear that the United States has a strong lead in having available a vehicle capable of conducting research in any part of the ocean itself. It is also apparent, from testimony offered by the operating crew, that the utilization of the *Trieste* is limited by two factors; first, the absence of a supporting mother ship and second, the inherent technological limits of the craft itself.[60]

The additional shore and ship facilities were defined by the project crew as critically necessary for the continued and effective operation of the *Trieste* in their testimony before the House Science and Astronautics Committee as follows:

Shore facilities for the bathyscaph are all located in the waterfront area of N.E.L. and, besides office space, include the following: A fenced concrete compound for drydocking stowage and shop spaces, and berthing space between two wooden piers.

Deficiencies in shore facilities include the following:

(*a*) The present fenced compound is inadequate, if another vehicle should be built and assigned to N.E.L.

(*b*) A ballast storage area should be provided.

[58] "Frontiers in Oceanic Research," op. cit., p. 27. See also New York Times, Jan. 25, 1960, p. 18, "Soviet designing bathyscaph."

[59] "Frontiers in Oceanic Research," op. cit., p. 31.

[60] With regard to logistic support, in reply to a question by Representative Anfuso, Dr. Rechnitzer said, "At the present time, our fleet consists of the *Trieste*, a converted landing craft and one small lobster boat. During our operations we require a towing vessel and this is assigned for the specific periods at which we expect to go to sea. Working with the Bathyscaph is somewhat like launching a missile. It isn't always ready to go at the specified date. We then have to fit it in with other Navy operations and sometimes we are forced to then sit on the beach and wait until we have our next reservation" ("Frontiers in Oceanic Research," op. cit., p. 35.)

(*c*) A fuel handling system capable of absorbing the 30,000-gallon fuel load of the *Trieste* should be provided at the facility.

(*d*) Shop space in the order of 5,000 square feet should be available and expandible to provide a machine shop, instrumentation shop, storage of delicate equipment and spare parts, work area for sphere instrumentation and repair, a darkroom for special deep-sea cameras, and a high pressure test facility.

(*e*) The berthing space for the *Trieste* should be a protected space which gives good insurance against waves from passing vessels, boarding by unauthorized personnel and maximum protection against possible fires. The group also has a 53-foot landing craft converted to a workboat and a 17-foot wooden lobster boat which is used as a tender boat during operations. These two craft require docking space near the bathyscaph.

(*f*) Machinery stowage space should also be provided.

(*g*) A stowage area for flammable fluids should be built.

The delicate bathyscaph was not built to withstand the stresses of a long tow at sea. During the recent operations on Project Nekton it was necessary to tow the craft for several days at a time through fairly rough sea conditions. At the completion of each tow and prior to diving a careful inspection was made of the craft and each time we found several items either destroyed or missing. Thankfully, nothing was damaged such that we could not make the dive; however, this was just a matter of luck and if we continue to operate in this fashion we will most certainly sustain a disabling casualty.

The large workboat cannot be taken to sea on any operation more than a few miles off the coast. The small tender boat can be put aboard the towing vessel for transport to the diving area.

The afloat facilities necessary to support the *Trieste* and other deep submersibles should consist of the following:

(*a*) A mother ship which is capable of picking up and cradling the vehicle or vehicles and the attendant small boats. This ship would also have numerous laboratory and shop facilities such that it would be a floating research facility capable of carrying out independent bathyscaph operations in any ocean. Until this ship is available the *Trieste* is virtually limited to coastal waters due to the extremely slow rate at which she can be towed.

(*b*) A converted LCM landing craft has been modified so that it is able to tow the *Trieste* in sheltered waters thus obviating the need for requesting a tugboat each time we wish to move the 120-ton bathyscaph.

(*c*) The small tender boat is a small lobster boat which now fills the bill perfectly.

(*d*) A rubber raft is often used when the seas are too high to permit the launching of the tender boat.[61]

It would seem that the logistic support for the *Trieste* is limited and incompatible with the research program outlined previously for which the vehicle was originally purchased.

That the bathyscaph has impressed its operators with the unique potential of making measurements from a fully submersible laboratory is abundantly clear. As a progenitor to manned descent to the bottom, has been deemed a major accomplishment, and those making the deep dives have been decorated by President Eisenhower. However, despite the superlative depth-seeking performance, by its very nature, the *Trieste* lacks maneuverability, endurance, payload-carrying capacity, and ruggedness necessary for extended and effective use by scientists wherein primary attention can be devoted to the task at hand, rather than to the operation of the vehicle itself.

The solution has been considered partly to lie in the promise of deep-diving true submarines, mentioned in Section IV–A. In essence, studies have revealed that through the use of unorthodox materials or geometric shapes, a true submarine can be designed that could safely descend to very great depths, with scientific payload, and eventually with combat payload, and yet derive buoyancy purely through dis-

[61] "Frontiers in Oceanic Research," op. cit., pp. 32–33.

placement of sea water, as an ordinary submarine does, rather than through the use of artificial flotation.[62]

High-strength aluminum alloys, among other new materials, offers this promise, and it was with this background that the *Aluminaut* concept, mentioned earlier, was evolved. Sponsored by Reynolds Metals Company as a proprietary research program at the Southwest Research Institute, the *Aluminaut* is now an accomplished submarine design. It is intended to operate to 15,000 feet, and with a range of 100 miles, an endurance of two days, a crew of 3 and a payload of scientific equipment weighing 2 or more tons.

Equipment planned for the boat, incidentally, includes a pair of remote manipulators (or prosthetic arms) which will make it possible for operators on the inside to pick up samples of minerals from the ocean floor, possibly net specimens, and perform engineering services by placing and maintaining devices on the ocean bottom. By operating to 15,000 feet, the *Aluminaut* will be able to explore the ocean from surface to bottom throughout 60 percent of its area.

Briefly, the *Aluminaut* comprises a cylindrical hull—7 feet inside diameter, 6 inches thick, roughly 33 feet long—enclosed at both ends by hemispherical shells. The stern is further tapered for streamlining and incorporates a propulsion and control capsule with diving fins and a swiveling propeller. Propulsion would be accomplished by silver-zinc storage batteries.[63]

When the project was initiated, it was recognized that the usefulness of a research vehicle would depend heavily on its being tailormade for oceanographic research. As consequence, contact was established by the designers with the Office of Naval Research through which continuing advice and consultation were offered to establish performance characteristics that would render the vehicle useful for studies in the ocean. While not intended for use as a combat vehicle, operation at 15,000 feet should prove highly interesting to naval planners.

With the design successfully completed late in 1959 and predictions of strength confirmed by tests of structural models early in 1960, steps are reported as being taken by which the vehicle will be constructed and built by the Reynolds Metals Co., but made available for oceanographic research to the U.S. Navy. Comments on this program were provided by Secretary Wakelin to the House Committee as follows:

> The Reynolds Metals Co. is designing and constructing the *Aluminaut*, a manned deep research vehicle. It is designed to operate to a depth of 15,000 feet with safety and convenience and with sufficient range, mobility, and endurance to satisfy even the most demanding requirements for an oceanographic research vehicle. The Navy will initially assist in designing and providing for this craft its scientific instrumentation. The Office of Naval Research is considering a proposal to lease the vehicle through the Woods Hole Oceanographic Institution. Another program for a manned maneuverable undersea research vehicle is funded in fiscal year 1961. This craft will be used to investigate problems in oceanography concerning deep undersea military applications and to assist in the design and feasibility tests of hull, control, propulsion and other components directly applicable to undersea vehicles for research, submarines or for weapon systems.
>
> There is no request for funds in the military construction appropriation for oceanographic facilities in fiscal year 1961.[64]

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[62] Feasibility studies of pressure hulls for deep diving submarines were first carried out for the Committee on Undersea Warfare, National Academy of Sciences-National Research Council, in 1957–58, by E. Wenk, Jr.

[63] "An Oceanographic Research Submarine of Aluminium for Operation to 15,000 Feet," by E. Wenk, Jr., R. C. DeHart, P. Mandel, and R. Kissinger, presented before the Institution of Naval Architects, London, Mar. 23, 1960.

[64] "Frontiers in Oceanic Research," op. cit., p. 64.

From the foregoing discussion it is clear that the United States, insofar as is known, has capabilities in terms of deep water vehicles, either in being or at the threshold of construction, that could maintain the United States in a position of leadership in this area. The United States has already been first to the bottom, so that in terms of purely spectacular achievement, this Nation is clearly in the lead. There remains, however, the systematic utilization of deep ocean vehicles in a coherent program of research which can come only when vehicles themselves are both available and provided with sufficient logistic support that those responsible for research can concern themselves with scientific observations rather than the idiosyncrasies and operational problems of the vehicles themselves.

In this regard, the *Trieste*, the *Aluminaut*, and, in fact, any other of these special vehicles will require a special mother ship either to tow or to handle the craft at sea. In terms of the present inventory, no ship has yet been assigned for this particular purpose. Dr. Rechnitzer in testimony before the House Committee in response to questions by Representative Fulton reports this development imminent:

Mr. FULTON. I am interested seriously, though, in how you were funded for your current operations. In the current fiscal year are your funds adequate?

Secondly, are your equipment and instruments adequate?

Thirdly, for the coming fiscal year, has there been any cutoff of any appropriation or authorization you have requested so that you are without any major equipment or ancillary equipment, for example?

Do you have a better equipped mother ship, or a better bathyscaph, or a more mobile bathyscaph, that you might do better than, what is it, 1 mile an hour laterally? Have you been cut off?

There has been a rumor around that you have received a cut by somebody.

Dr. RECHNITZER. I think that we are being adequately funded for the coming fiscal year, and that progress toward an adequate mother ship is moving along just as fast as it is practicable.

Mr. FULTON. Then you have not in any respect had an appropriation cut, either in the current fiscal year, or a cut in the request for authorization in the next fiscal year?

Dr. RECHNITZER. We will not know probably until some time after the end of the fiscal year just where we do stand.

Mr. FULTON. Yes, but at the present time there is no cut that you are complaining about?

Dr. RECHNITZER. No, I have no serious complaint.

Mr. FULTON. Is the appropriation adequate enough to keep you moving on your research on a level with the Russian effort?

Dr. RECHNITZER: Yes, as far as we can see in the coming year, we will certainly continue to be ahead of the Russians. There is definitely room for expansion in this field. More people, better vehicles, and more minds and hands need to be put to the task of getting more manned vehicles into the deep sea.[65]

At the time this report was prepared, no assignment had yet been made of a mother ship.

In discussing the present inventory of manned vehicles for operation in deep water, sight should not be lost of a rich variety of other manned and unmanned vehicles and devices which oceanographers desire for research and which are totally nonexistent.

[65] "Frontiers in Oceanic Research," op. cit. pp. 38-39.

Such items would include manned research platforms, both floating and located on the ocean bottom; anchored and drifting buoys, both manned and unmanned; aircraft for joint operations with surface ships; surface icebreakers; and various types of heavy engineering equipment for undertaking heavy operations in the sea such as drilling.

3. Shore-Based Facilities

No inventory of shore-based facilities was included in the NASCO study. It is apparent, however, that the conduct of research is as vitally dependent on laboratories, specialized scientific equipment, shops, office space, and data processing equipment as it is on ships and deep-sea vehicles. Data for the major laboratories conducting research under sponsorship of the Navy were collected for Project TENOC, and additional items of unpublished information now reside at NAS–NRC. Because it is somewhat fragmentary, no attempt has been made to tabulate this information as was done for the ships. Moreover, even if the square feet of floor space were summarized, interpretation of these bald statistics alone would be difficult. Oceanographers point out, however, that the present facilities are crowded and inadequate if one considers the age of buildings which house these operations, and the lack of new construction during the interval that this research was expanding.

D. FUNDING

Having defined the ingredients of organizations conducting research, the status of U.S. manpower and facilities, and having noted in some detail the unfulfilled potential of research in the oceans, the inevitable fact must be faced that the success and vitality of any program depends on adequate and continuous funding. Plans, policies, and intentions are meaningless without this significant energizing factor and whereas most research administrators, in moments of candor, admit that goals are best achieved when operating somewhat hungry, the debilitating effects of starvation are well known. Funding, as manpower, has been a significant factor on the rate of advance.

Recent figures and trends have been collected by the National Academy of Sciences, and additional data have been developed for purposes of this report from U.S. Navy and other Government sources. Because of differences in definitions, and in budget classification and accounting practices, it has been exceedingly difficult to find a common base to which fiscal data from all sources could be referred. Tables which follow contain explanatory notes by which discrepancies have been reconciled.

In the first instance, since Fiscal 1958 has been used as a base for evaluating the current level of effort and for proposals for future expansion, NASCO data on funding for that year is given in Table 10. Support that year from both Federal and non-Federal sources was $23,626,000. To this amount should be added, for Fiscal 1958, $3.69 million U.S. Navy funds for rehabilitation of ships *Chain*, *Snatch* and *Gibbs* and for purchase of the bathyscaph *Trieste;* and $2.99 million for direct and ship operation costs for hydrographic surveying by the Coast and Geodetic Survey. The revised totals and sources of financial support are given in Table 11.

56612—60——7

TABLE 10.—*Sources of financial support in various kinds of oceanographic laboratories, fiscal year 1958*

[Dollar amounts in thousands]

	Large university	Small university	Large fishery	Small fishery	Navy [1]	Total
Number of laboratories	6	19	6	24	5	60
U.S. Government:						
Bureau of Commercial Fisheries	$248	$526	$2,895	$1,617		$5,286
Office of Naval Research	3,598	379	35			4,012
National Science Foundation	1,277	130	20	9		1,436
Atomic Energy Commission	196	149		325		670
Other	983	1		213	[1] $4,808	6,005
State funds	581	567	36	594		1,778
Total State and Federal funds	6,883	1,752	2,986	2,758	4,808	19,187
Endowments and grants	1,001	360		16		1,377
Other funds	2,281	318	353	110		3,062
Total	10,165	2,430	3,339	2,884	4,808	23,626

[1] Does not include ship operating costs. The oceanographic work at 3 Navy-operated laboratories and 2 laboratories operated under contract by a single Navy agency is included in this category. Also includes U.S. Navy Hydrographic Office, Division of Oceanography.

Source: NASCO report, ch. 12, table 2.

TABLE 11.—*Sources of financial support for oceanographic research, fiscal year 1958, as revised*

[In millions of dollars]

		Funds	Percent support
U.S. Government		24.10	79.5
U.S. Navy	13.71		
Bureau of Commercial Fisheries	5.29		
Coast and Geodetic Survey	2.99		
National Science Foundation	1.44		
Atomic Energy Commission	0.67		
State funds		1.78	5.9
Endowments and grants		1.38	4.6
Other funds		3.06	10.0
Total		30.32	100.0

SOURCE: NASCO Reports, Ch. 1 and 12; U.S. Navy, and U.S. Coast and Geodetic Survey

As noted previously, data cited in the NASCO report exclude funds for military oceanography and funds for operation of research ships whose program is devoted to military oceanography. Reiterating, programs in military oceanography are inclined to be heavily oriented toward development of hardware, and thus are not in the category of research within the intent of those considering the present posture of the United States. Moreover results are usually classified, and thus denied the public access that characterizes scientific results. In the case of ship operating costs in the category of military oceanography, the budgets are usually imbedded in much broader accounts for units of the fleet engaged in general development, test, and evaluation activities, and thus exceedingly difficult to separate. Moreover, these same ships often engage in a plurality of missions including training of crew such that assignment of costs for a single phase of their program would be clearly impracticable. Certain survey and oceanographic activities of the Navy Hydrographic Office were included by NASCO, but in now being classified, are regarded by the Navy as military oceanography.

The conduct of oceanographic research by performance component is given in Table 12. It is compared with the total funds for the entire Federal program of Research and Development and with that sector of the program devoted to basic research for the same fiscal year. On this basis, it will be noted that oceanographic research represents 2.4 percent of the federally supported basic and applied research activity. Subsequent to 1958, funds devoted to oceanographic research have increased. In Fiscal 1959, Federal support was $18 million, but in Fiscal 1960, it rose to $39 million, excluding Navy Hydrographic Office activities. Budget recommendations for Fiscal 1961 submitted by the President to the Congress total $55.75 million; see Table 25.

TABLE 12.—*Conduct of Federal research and development by performance component, fiscal year 1958*

[In millions of dollars]

	Total funds	Intramural	Profit organization	Educational institutions	Nonprofit organizations
Entire Federal program, R. & D [1]	5,542	1,445	3,509	478	109
Entire Federal program, basic and applied research [1]	1,034	(2)	(2)	(2)	(2)
Entire Federal program, basic research	331	115	18	166	32
Federal support of basic and applied oceanography, not including military oceanography	24	(2)	(2)	(2)	(2)

[1] Source: "Federal Funds for Research VIII" NSF 59-40 (Federal obligations).
[2] Not available.

Within the Navy itself, funding for research and development for the fiscal years 1958, 1959, and 1960, is compared with that segment for oceanographic activity in Table 13:

TABLE 13.—*Navy support of oceanography in comparison with its entire program*

[In millions of dollars]

	Total research and development [1]	Total research [2]	Oceanography [3]
1958	885.16	102.27	5.65
1959	1,249.49	125.88	5.70
1960	1,298.23	135.30	13.89
1961 (projected)	----------	----------	17.72

[1] Federal obligations for the conduct of research and development, thus including development, test, and evaluation; source: "Federal Funds for Research" National Science Foundation, 59-40.
[2] Federal obligations for conduct of research.
[3] Estimated appropriations including carryover. Figures do not include costs of ship operation or for conversion or construction of new ships, or any operations of U.S. Hydrographic Office, now considered as classified.

Source: Office of Naval Research and "Federal Funds for Research VIII" NSF 59-40.

Oceanographic activities embrace something more than "research," but less than "research and development." Direct comparison of figures is thus not valid. However, it is clear, that insofar as funding from U.S. Navy is concerned, the support for oceanography has increased markedly within the past three years, well beyond the proportional increase in funds for research, or for research and de-

velopment generally. The same trends are beginning to develop in the National Science Foundation, but not among other civilian agencies, as is demonstrated in Table 14.

TABLE 14.—*Recent trends in Federal funding of oceanographic research*

[In millions of dollars]

Fiscal year	Navy [3]	C & GS	B of CF	NSF	AEC	Total
1957	6.08	(1)	(1)	(1)	(1)	(1)
1958	[2] 9.34	2.99	5.29	1.44	0.67	19.73
1959	5.70	3.19	5.5	2.476	1.575	18.45
1960	[2] 19.09	[2] 5.67	6.15	[2] 6.80	1.82	39.53

[1] Not available; in 1957, included in other programs.
[2] Includes the following for ship construction or conversion: Navy 1958—3.69; Navy 1960—5.2; C. & G.S. 1960—2.0; NSF 1960—3.0.
[3] Excludes all Hydrographic Office activities.

Source: Interagency Committee on Oceanography.

E. FEDERAL AGENCIES HAVING OCEANOGRAPHIC RESPONSIBILITIES

In view of the broad implications of the sea in terms of military, commercial, political, economic and scientific affairs, it is to be expected that cognizance over various aspects of oceanic research is a matter of concern to the Federal Government. At present, some 19 or so departments and agencies have statutory jurisdiction over different sectors of the field; those having well defined interests are listed in the following; those with largest marine budgets are "starred" (*).

1. U.S. Navy

Since the oceans are the Navy's primary domain and since the Navy, in providing for the national defense, must both protect our shores against attack and maintain the seas free for commerce, it must develop an understanding of the surface of the sea, of the ocean bottom, and of the relationships between the ocean and its atmospheric boundary.

Historically, the U.S. Navy undertook responsibilities for understanding the sea in 1842 when Lt. Matthew Fontaine Maury was appointed Superintendent of the Depot of Charts and Instruments, which later became the Hydrographic Office. Charting of the seas became routine and the Navy enlisted voluntary contributions of data from the merchant fleet as well as from deliberate hydrographic surveying. It was not until World War II, however, that the fine structure and detail of the sea became a critical factor in undersea warfare through the recognition that submarines could conceal themselves from acoustical detection, as discussed previously.

Development of apparatus for the detection of enemy submarines and quieting techniques for the protection of our own was the responsibility of the Bureau of Ships which, during World War II, was the primary military sponsor of studies in the ocean.

When the Office of Naval Research was created by Public Law 588 on August 14, 1946, it undertook the sponsorship of a much broader program in oceanography.

Thus, at the present time, three units within the Navy have major responsibilities regarding oceanic research: The Hydrographic Office, the Bureau of Ships, and the Office of Naval Research; interest by others is developing.

(*a*) *Hydrographic Office.**—The Hydrographic Office was formally established by an act of Congress approved June 21, 1866, charged

with "improvement of a means for navigating safely the vessels of the Navy and of the mercantile marine by providing, under authority of the Secretary of the Navy, accurate and cheap nautical charts, sailing directions, and manuals of instructions for the use of all vessels in the United States and for the benefit and use of navigators, generally."

Up until 1928, oceanographic information was confined primarily to bottom soundings and information concerning the ocean surface; but in that year, as a result of inquiries of the first Committee on Oceanography of the NAS, the Hydrographic Office expanded its program.

During World War II these activities were further expanded and particularly in June 1943, the Hydrographic Office was given responsibility for furnishing oceanographic information required by all the armed services. To conserve the know-how accumulated during World War II, the Division of Oceanography was established immediately after the war, although some of its responsibilities subsequently were absorbed by the Office of Naval Research.

The preparation of manuals, atlases and tables has been a particularly important contribution of the Hydrographic Office. Samples include:

HO 607, an instruction manual of oceanographic observations—a cookbook of how to obtain all types of data.

HO 606C, a pamphlet on taking bathythermographic observations.

HO 614, a standard treatise, internationally accepted, on the processing of oceanographic data.

HO 604, on the forecasting of waves.

At the present time, the Hydrographic Office operates the major segment of research vessels devoted explicitly to charting and these have been previously listed in Table 8. Virtually all of these activities are now focused on classified projects and as a consequence, for program and budget purposes, activities of the Hydrographic Office are now considered by the Navy as a phase of military oceanography.

(*b*) *Bureau of Ships.**—The Bureau of Ships has responsibility for the design, construction, maintenance and overhaul of all elements of the U.S. fleet, including all of the technical equipment placed on board, with the exception of weapon systems. It is thus responsible for the development of such materiel as needed for the detection, tracking, and classification of undersea targets, making use of underwater acoustics, disturbances of the Earth's magnetic fields by underwater bodies and other phenomena. Quite obviously, the improvement of performance of such equipment and the development of new principles require a detailed understanding of the ocean, the physical and chemical properties of its contents, etc. The manner in which oceanographic research contributes to improved antisubmarine defense, for example, was cited in testimony by Secretary Wakelin:

1. *Q.* In what way will oceanographic research contribute to an improved antisubmarine defense for the United States?

A. The present antisubmarine defense for the United States is based almost entirely upon the use of underwater acoustics. This applies to open ocean surveillance, submarine detection, localization and classification as well as to the operational use of ASW weapons systems. Oceanographic research will contribute an improved antisubmarine defense by providing us with an understanding of, or a working knowledge of the following phenomena of the sea:

(*a*) Effect of wind on the water surface in producing ambient noise;

(b) Effect of sea state and swells in producing sound scattering, reverberation, and ambient noise;

(c) Effect of the thermocline, salinity, biological organisms, and internal waves on sound propagation and volume reverberation for sonar systems;

(d) Effect of deep velocity profiles on propagation of long-range sonar signals;

(e) Effect of the slope, roughness, and reflectivity of the sea floor on bottom reflection characteristics;

(f) Means to predict the thickness and temperature gradient of upper water layers to determine the propagation for surface sonar systems; and

(g) Effect of ice thickness, roughness, and composition on acoustic scattering and reverberation.

In addition, oceanographic research is required to explain many of the phenomena associated with nonacoustic methods of submarine detection now under study. It is anticipated that it will serve as the basis for understanding or for evaluating detection methods yet to be devised.

2. Q. (a) Does the Navy have an operational requirement for oceanographic research?

(b) Is it regarded as part of the ASW program and what priority does it enjoy?

(c) Could you trace the Navy's program in oceanography over the past 5 to 10 years?

A. (a) The Navy's program for basic research in oceanography is contained in the TENOC program (for 10 years in oceanography). This document describes the research supported by the Navy in nongovernmental laboratories and institutions. In addition, the Chief of Naval Operations has provided the technical bureaus with operational requirements for military systems in which oceanographic research is necessary.

(b) *The oceanography program is included in the Navy ASW program and enjoys the same high priority.* [Emphasis added.]

(c) Since World War II the Navy has been the principal supporter of oceanography in the United States. Recognizing in early 1956 that the needs for knowledge of the oceans were increasing more rapidly than were the capabilities of the science, the Navy, with the Atomic Energy Commission and the Bureau of Commercial Fisheries, was instrumental in the establishment of the Committee on Oceanography under the aegis of the National Academy of Sciences, National Research Council.[66]

To a great extent, the problems sponsored by the Bureau of Ships tend to have specific practical goals and in the main involve military security classification. As a consequence, with few exceptions, these activities are also regarded as in the category of military oceanography.

Inasmuch as the preponderance of naval action has, in the past, occurred at the sea surface, hulls have had to be designed so as to provide naval vessels with the highest possible performance in terms of speed and maneuverability, in both calm and rough waters. Until recent years, most of the designs have been optimized in terms of smooth water operation. Hull shapes were almost exclusively conditioned by results from model tests conducted in still water basins, in the belief that the behavior of the sea was itself so complex as to defy description or understanding necessary for consideration as a design parameter.

Provisions have now been incorporated in such test facilities to simulate wave action, but even more exciting and significant has been the application of more sophisticated tools of hydrodynamic research wherein the apparently random and confused pattern of the sea can be mathematically described. Naturally, any such abstract representation depends upon correlation with data collected from the sea itself and there is now a rapidly growing area of interest and activity within the Bureau of Ships to observe and describe the sea so as to be able to represent it adequately in future hull design. A great deal of this activity is undertaken at the David Taylor Model

[66] "Frontiers in Oceanic Research," op. cit., pp. 62–63.

Basin in Carderock, Md. Other similar research is being sponsored at universities and nonprofit institutions. At the present time, this program, although unclassified, has not been included in the inventory of oceanographic research either by the Navy or others; instead, it has been associated with hydrodynamic programs in naval architecture.[67]

(c) *Office of Naval Research.**—There remains an exceedingly broad area of basic research critically necessary for the preservation of U.S. naval superiority. Applications of such knowledge are frequently unpredictable and the philosophy of the Office of Naval Research has thus been to foster a broad program in a wide variety of fields to improve an understanding of the ocean itself, leaving for the Bureau of Ships and other materiel bureaus the possible application of results. Programs by the Office of Naval Research are conducted, to a great extent, through contract with universities and non-profit laboratories to which should be added their support of collateral studies at their own facilities, the Naval Research Laboratory in Washington, D.C. A list of typical studies conducted by the Office of Naval Research is given in the following:

TABLE 15.—*ONR program in basic oceanic sciences*

1. Wave studies, including long swells, and spectra of random wave heights and frequency of occurrence.
2. Tides and tidal currents.
3. Geology in the deep sea, including sea mounts, fracture zones and causes of these features; seismological structure of sediments, bottom photographs, beach and bay formation, flushing of estuaries.
4. Physical oceanography, including distribution, random and seasonal variations of surface and deep currents, temperature, transportation of sediments, molecular properties of water using infrared techniques, water motions at various depths.
5. Geochemistry, including determination of age of sediments, distribution of chemical elements in sea water, processes of diffusion and mixing.
6. Geophysics, including observations of Earth's magnetic and gravitational field, at the surface and near the bottom, light scattering and transmission.
7. Acoustical properties, including transmissibility, reverberation effects, ambient background noise, thermal micro-structure of the sea and its effects, sound channel phenomena, transmissibility in sediments, sound scattering by plankton.
8. Radioactivity studies, including background of radioactive isotopes in the ocean normally, and as a consequence of various types of disturbances.
9. Marine biology, including ecological and population dynamics of plankton, estuarine pollution and other effects contributing to deterioration of anti-fouling measures, development of anti-fouling paints, role of bacteria in nutrient cycle of fish.
10. Oceanic meteorology, including studies of heat budget of the Earth, and energy exchanges between sea and atmosphere, interaction of wind and waves, wave forecasting.
11. Chemical oceanography concerned with demineralization of sea water, chemical waste disposal.

(d) *Bureau of Naval Weapons.*—Representing the 1959 consolidation of the Bureau of Aeronautics and the Bureau of Ordnance, the Bureau of Naval Weapons has a prime responsibility for the Navy of developing devices and systems for the destruction of hostile craft in the air, on, and under the sea. Inasmuch as many of these weapons are either focused on destruction of submarines or are initially launched from submarines, the Bureau has the same vital interests in the properties of the ocean as does the Bureau of Ships. Homing acoustical

[67] The interdisciplinary nature of the marine sciences is discussed subsequently in the context of providing an additional reason for coordination to make the most effective use of scarce manpower.

torpedoes must be made to operate undistracted by the normal background noise within the sea; pressure mines must be able to sustain fluctuations due to surface waves, tides, etc., without inadvertent detonation. Virtually all of the activities in this area are regarded for the moment as representing military oceanography, but a small amount of fundamental research has been initiated in such organizations as the Naval Ordnance Laboratory, White Oaks, Md. and the Naval Ordnance Test Station in Inyokern, Calif.

(*e*) *Bureau of Yards and Docks.*—The Bureau of Yards and Docks has responsibility for the Navy of the design, construction, and maintenance of all shore bases and fixed facilities. In the past, this has primarily involved the more conventional piers, docks, and shipyard facilities. But, with the Navy now concentrating attention on the sea itself and the ocean bottom, expansion may be expected in the capabilities of the Bureau of Yards and Docks to provide such items as fixed platforms deep within the ocean or located on the ocean floor, systems for placing and recovering heavy loads in deep ocean water and for the servicing of deep ocean structures or equipment. Both basic and applied research with this deep water emphasis has been recently initiated on a modest scale at the Naval Civil Engineering Laboratory at Port Hueneme, Calif.

2. U.S. Coast Guard

The U.S. Coast Guard is responsible for maintaining the International Ice Patrol and ocean rescue stations. In discharging this responsibility, it must locate, count, and track icebergs, study currents around Labrador and Greenland. The Coast Guard also studies wave motions to analyze the interaction of wind and sea, as, for example, to determine the most desirable heading to land an airplane in the unhappy circumstance when it is necessary to ditch at sea. In the application of its statutory duties, the Coast Guard has also considered study of oil pollution of coastal waters. Through its severe limitation of personnel and budgets, the Coast Guard has been precluded from engaging in any extensive program of its own. It does, however, assume senior management responsibility for the Ship Structure Committee (SSC), along with cosponsors of the Navy, Maritime Administration, and American Bureau of Shipping (funds are contributed primarily by Navy). This organization, initially formed in 1943 to investigate the brittle fracture of merchant ships at sea, through contract research conducted under auspices of the National Academy of Sciences—National Science Foundation, is now turning its attention to the much more general problem of the rational rather than empirical design of ships. In turn, this philosophy has suggested need for data on loads imposed by the sea on ship hulls, and the response of the hull structures and materials. As part of the first problem, the long-range plans of the SSC now include observations of the sea and the development of techniques for the collection of synoptic data, together with research on wave generation and decay through interaction of wind and waves as a basis for wave forecasting.[68]

[68] "A Long-range Research Program in Ship Structural Design," SSC-124, November 1959, U.S. Coast Guard.

3. Department of the Interior

(*a*) *Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service.**—The Bureau of Commercial Fisheries is responsible for extensive programs in support of all types of fishery interests, including particularly biological aspects of oceanography. The Bureau maintains a number of laboratories for the purpose of studying those characteristics of the ocean which affect fish and fishing. These have been included in the survey, Tables 3 and 4. Programs of the Bureau of Commercial Fisheries cover the following topics:

1. Plankton sampling.
2. Behavior of marine animals.
3. Artificial cultivation of young fish and shellfish.
4. Distribution of marine populations.
5. Biological surveys and inventories of the ocean.
6. Taxonomy of marine species.
7. Genetics of marine organisms.
8. Pond fish culture, brackish water farming.
9. Effects of industrial and domestic waste on estuaries.
10. Study of disease and parasites and their effects in marine ecology.
11. Transplantation of organisms.
12. The potential of artifically increasing nutrients.
13. The utilization of new marine products.
14. The improvement of fishing techniques and equipment.
15. The economy and legal aspects of commercial fisheries.

(*b*) *U.S. Geological Survey.*—The U.S. Geological Survey is interested in the possible presence and significance of minerals located in bottom sediments extending out on the continental shelf. It is thus particularly interested in the geological structure of offshore lands, an inventory of subsurface resources and in development of techniques for determining the presence of subsurface minerals. This agency maintains only a limited program in oceanic research.

(*c*) *Bureau of Mines.*—The Bureau of Mines has statutory responsibilities concerned with the exploitation of mineral wealth of the United States and would thus have cognizance over the assessment of potential value and means of recovering and utilizing mineral resources in and under the sea. This would include the extraction of minerals from sea water, the underwater mining of nodules and the extraction of coal or oil from subsurface fields. Although the Bureau maintains independent laboratories, virtually none of its efforts is devoted to oceanic research at the present.

4. Department of Commerce

(*a*) *Coast and Geodetic Survey.**—The Coast and Geodetic Survey operates a small but efficient fleet concerned with charting in the continental shelf areas. However, limits on its geographical areas of jurisdiction were relaxed by Public Law 86–409, approved April 5, 1960. Historically, this agency was derived from the Survey of the Coast, established by President Thomas Jefferson more than 150 years ago. It has particularly concentrated on soundings in the offshore areas, including Alaska, and has actively participated with the Atomic Energy Commission in surveying offshore sites for the disposal of low-level packaged, radioactive waste. The Coast and Geodetic Survey has undertaken development of a number of systems of

precise navigation. The C. & G.S. also has responsibility for predictions of tides and has established warning systems for *tsunamis*, the seismic sea waves which accompany submarine earthquakes.

Activities of the Coast and Geodetic Survey, in terms of ships and funds, have been included in the previous tables.

(*b*) *Weather Bureau.*—The Weather Bureau has an interagency responsibility for weather forecasting, for hurricane warnings, and for the conduct of research on weather modification. As noted in Section V, the weather, which is a phenomenon of the atmosphere, is directly coupled in the heat budget of the planet Earth with the seas and, as a consequence, the Weather Bureau has a very direct interest in both surface and subsurface currents, in the physics of heat exchange between the atmosphere and the ocean at the interface, and on local phenomena which trigger the birth of storms. It currently sponsors a small amount of extramural research.

(*c*) *Maritime Administration.*—The Maritime Administration has a statutory responsibility to foster a merchant marine of the United States, both for defense and commercial purposes. It is thus fundamentally interested, along with the Bureau of Ships, in research and development concerned with seakeeping of ships, in investigations concerned with stresses induced in ships' hulls by the sea, and with methods for obtaining data concerning wind and sea state by which ships may be routed so as to arrive at their destination in the least time and with the least damage to cargo.

The most recent study of the role of the U.S. Merchant Marine in national security was developed through a special committee of the National Academy of Sciences—National Research Council and published as "Project Walrus." With the objective of "examining the present and future military demands on the U.S. Merchant Marine in order that technical requirements can be derived for maritime research and development planning," it became clear to those undertaking the study that the U.S. Merchant Marine was deteriorating. Among other points, it was recommended that "The Maritime Administration should earnestly pursue opportunities for coordinating facilities, for the conduct of scientific, engineering and economic research in support of the entire maritime industry," and "research and development * * * should be directed toward * * * (*a*) developing a self-supporting U.S. Merchant Marine which can compete successfully in the world market (possibly achieving a competitive status relative to foreign merchant fleets through higher speed) and (*b*) developing a U.S. Merchant Marine which will be of the greatest possible use with sound operations for national defense purposes."[69] Projects were recommended to study improved hull forms for higher sustained speeds and on the loads experienced by ships at sea. Recommendations were also made to collaborate with the military services in design of submarine tankers and of submersible barges pushed or towed by combatant submarines.

At the present time, the Maritime Administration has no oceanographic research program or capabilities but it is possible, in light of these recommendations, that their participation may emerge. In the meanwhile, they share sponsorship of the Ship Structure Committee.

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[69] "Project Walrus," op. cit., p. 15.

On the other hand, the Maritime Administration has noted that "it should be consulted in designing of all ships, paid for from public funds and used for marine studies * * * and charged with the supervision during construction of Government-owned oceanographic survey ships operated by others in pure research."[70]

(*d*) *National Bureau of Standards.*—The National Bureau of Standards has specific responsibilities concerning the calibration and standardization of instruments employed in research and on standard properties of water, etc. In addition, the National Bureau of Standards has been given a responsibility for research on techniques of data collection, storage, and retrieval such that their experience may prove applicable and valuable in the future development of centers for hydrographic or oceanographic data.

*5. Atomic Energy Commission**

The Atomic Energy Commission is concerned with oceanographic research and development insofar as it relates to their responsibilities for disposal of radioactive waste products. Of the two types of waste products, low-level and high-level, the philosophy to prevent contamination has been to dilute and disperse the first, to concentrate and contain the second. Studies by the Atomic Energy Commission and subsequently by independent research agencies, including NAS–NRC, have pointed to the feasibility of utilizing offshore waters. However, because of the irreversible action of such dumping, the safety of this continued practice has been a matter of serious and elaborate study by the Atomic Energy Commission, through their own laboratories and contracts with universities and nonprofit laboratories. They maintain no seagoing facilities of their own, but have contracted for such services. The extent of AEC sponsorship of this type of research has been previously noted in this report.

*6. National Science Foundation**

The National Science Foundation, in accordance with its enabling act of 1950, has undertaken an increasing responsibility to sponsor fundamental research in the oceans. This has been accomplished through grants to universities and nonprofit laboratories as shown in the accompanying tables. Quite recently the National Science Foundation has requested and received appropriations from the Congress for the construction of the first new oceanographic research vessel of any size to be built in this country. Details are given in Table 9. Although the National Science Foundation's support of marine sciences has in the past been relatively modest, it is visualized as having a vitally important role in the future in the support of research, as well as the construction of special facilities and the development of fellowship programs that would foster an increase in scientific manpower. An even greater role as an operating agency has been proposed by the Magnuson-Pelly Bills, as is brought out subsequently.

7. Department of Health, Education, and Welfare

The Department of Health, Education, and Welfare, through the Public Health Service, has a continuing interest in the problem of radioactive contamination of the ocean resources and their effects through the biological chain on human health. In addition, in the

[70] "Oceanography in the U.S.," op. cit., p. 71.

matter of fellowships and improved facilities for teaching, HEW may have an expanding responsibility as it relates to oceanography.

8. U.S. Army—Beach Erosion Board

The Army has had continuing interest in the gross behavior of the sea as it concerns amphibious operations in the oversea movement of troops and supplies. The Beach Erosion Board, however, has had interest in certain details of oceanic research. This organization, established during the 1930's and beginning a formal program of research in 1946, deals with shallow water oceanography as it relates to action of waves on beaches in their normal state and on engineering relevant to the placing of structures to remedy this action should it be considered detrimental. Research facilities are located primarily at the laboratory in Washington, D.C. The budget of the Beach Erosion Board has not been included as part of the national oceanographic research program proposed by NASCO presumably because it is largely of an engineering nature, but the relationship of their activities to other studies of the sea is obvious.

9. U.S. Air Force

The Air Force has had an interest in the broad aspects of the sea as it relates to navigation over the sea, to the performance of radar and missile ranges in the proximity of the sea and to the location and means of survival of flyers downed in the sea.

10. Department of Justice

The Department of Justice has responsibilities concerned with the application of law at sea, both in territorial and international waters.

11. Department of State

Inasmuch as the Department of State has broad and far-reaching responsibilities for the national security of the United States and the fostering of favorable relations with other countries, virtually all of the military, economic, political, and even scientific implications of the sea, in one manner or another, may be regarded as coming within its jurisdiction: directly as it relates to treaties on such matters as continental limits and fishing rights; indirectly, as it relates, for example, to fostering of media for the international exchange of oceanographic data and cooperation in international expeditions.

From this recitation of various Government agencies having an interest in activities in the sea, a number of functions appear to overlap. Both the Office of Naval Research and the National Science Foundation, for example, have statutory responsibilities for the sponsorship of basic research, and for fostering new facilities. The Hydrographic Office and the Coast and Geodetic Survey have parallel responsibilities in relation to the charting of the oceans. The Atomic Energy Commission and the Public Health Service have complementary responsibilities concerning protection of present and future welfare of the health of the Nation from adverse biological effects of radioactive waste; questions of policing may involve yet other agencies.

Whereas this matter of possible overlap is of concern to some in terms of unknowing and thus wasteful duplication, an even greater and more likely malfunction in Government may occur when some critically important project is neglected, either because each agency pinched for funds has pious hopes that the other is assuming cogni-

zance, or because all inadvertently overlook the needed program so that it falls unnoticed "in the cracks in the floor."

When a large number of agencies have responsibilities for different segments of the total program, some of these segments tend to be small. Each segment must be defended for funds in its cognizant agency against a large number of other projects, and in the competition, despite sought-for balance, some fare poorly. As a result, since often one part of a program developed by one agency may depend on a collateral phase sponsored by another, the loss in appropriations within one agency may well generate an enfeebling reaction throughout the entire matrix of oceanographic research.

All of these comments thus lead naturally to the everburning question in Government operations of mechanism and effectiveness of "coordination."

F. COORDINATION OF FEDERAL OCEANOGRAPHIC ACTIVITIES

Coordination of multi-agency activity is always desirable in principle, not just for administrative tidiness, but to assure the most effective pursuit and thrift of programs. In a potentially expanding field, such coordination assumes particular significance. Facts concerning existing procedures have been discussed in presentations to various committees of the Congress, particularly by representatives of the U.S. Navy and pertinent excerpts are presented in the following:

The first move toward informal interdepartmental coordination developed in 1956 with formation of the *Coordinating Committee on Oceanography* (CCO), described by Vice Adm. John T. Hayward: [71]

> While the Navy is pursuing its own program in oceanography, the problems are so large and involve so many other groups that it has been found necessary to coordinate our research within the Department of Defense and other Government agencies. Within the DOD formal coordination is achieved through the Committee on Science which has designated service representatives to deal with oceanography. Coordination among other interested Government agencies is accomplished informally through the Coordinating Committee on Oceanography (CCO) established by the Office of Naval Research in 1956. This committee, consisting of representatives from all Federal agencies concerned with the oceans, has met regularly every month to discuss problems of mutual interest.

Then with regard to its functions, Rear Admiral Hayward added:

> The usefulness of the Coordinating Committee on Oceanography is attributed to its informality and to the rotation of the chairmanship among the member agencies. It is this group that will insure that a national program in oceanography is properly managed and well coordinated throughout the Federal agencies concerned.

The Coordinating Committee on Oceanography currently includes representatives from the following agencies:

- Health, Education, and Welfare.
- Public Health Service.
- National Science Foundation.
- Beach Erosion Board, Corps of Engineers.
- Bureau of Ships, U.S. Navy.
- Maritime Administration.
- Bureau of Commercial Fisheries, Fish and Wildlife Service.
- Office of Science, Department of Defense.
- Office of Naval Research.

[71] "Oceanography in the U.S.," op. cit., p. 135.

Bureau of Mines.
Weather Bureau.
Department of State.
Geophysics Branch, U.S. Air Force.
Atomic Energy Commission.
U.S. Coast Guard.
Hydrographic Office, U.S. Navy.
Bureau of Weapons, U.S. Navy.
U.S. Coast and Geodetic Survey.
National Academy of Sciences, Committee on Oceanography.

By early 1959, 3 years after the CCO had been in operation, a number of events had focussed an unusual spotlight on the allegedly neglected status of oceanography in the United States and by virtue of the dominant role of the Federal sponsorship, on the question of adequate coordination. In particular, the NASCO study, begun late in 1957, was essentially complete, and its forceful recommendations had been made public. Also by early 1959, the Navy had itself constructed a long-term program of contract oceanic research, Project TENOC. Finally, in a report of the President's Science Advisory Committee released December 27, 1958, still additional emphasis on the need for an accelerated program was generated:

> Oceanography is another promising field which has received inadequate attention. For the study of the oceans, the United States has only a few research vessels, all inadequately equipped. A vessel specifically designed and constructed for oceanographic research has not been built in this country since 1930.

In that same statement, the President approved the establishment of a New Federal Council for Science and Technology (FCST) that was formalized subsequently by Executive Order 10807 dated March 13, 1959. Because this new organization has been delegated executive responsibility for coordinating oceanography, among other scientific fields, its functions, designated in Section 2, paragraphs (a) and (b) have been reiterated for background:

> SECTION 2. *Functions of Council.*—(a) The Council shall consider problems and developments in the fields of science and technology and related activities affecting more than one Federal agency or concerning the overall advancement of the Nation's science and technology, and shall recommend policies and other measures (1) to provide more effective planning and administration of Federal scientific and technological programs, (2) to identify research needs including areas of research requiring additional emphasis, (3) to achieve more effective utilization of the scientific and technological resources and facilities of Federal agencies, including the elimination of unnecessary duplication, and (4) to further international cooperation in science and technology. In developing such policies and measures of the Council, after consulting, when considered appropriate by the Chairman, the National Academy of Sciences, the President's Science Advisory Committee, and other organizations, shall consider (i) the effects of Federal research and development policies and programs on non-Federal programs and institutions, (ii) long-range program plans designed to meet the scientific and technological needs of the Federal Government, including manpower and capital requirements, and (iii) the effects of non-Federal programs in science and technology upon Federal research and development policies and programs.
>
> (b) The Council shall consider and recommend measures for the effective implementation of Federal policies concerning the administration and conduct of Federal programs in science and technology.

In view of the publication of the various 10-year programs for oceanographic research, of simultaneously emerging needs for interdepartmental coordination, and of the President's directive concerning responsibilities of the then-imminent FCST, an important meeting was

convened on February 24, 1959, by Secretary of the Navy Gates to discuss the NASCO report, and the possibility of developing a more formal interdepartmental mechanism to formulate and coordinate Government management policies in oceanography.

Results of the meeting were summarized by Rear Adm. Rawson Bennett, Chief of Naval Research, in a letter of March 19, 1959, to those who attended, as follows (made available by the Office of Naval Research):

The results of the meeting are as follows:

1. The agencies agree that the NAS–NRC Committee on Oceanography has issued a report of prime significance which must be carefully considered. Most agencies are not yet prepared to commit themselves on the budgets presented in Chapter 1, "Summary Report on Oceanography."

2. In the discussion of the requirement for a formal interagency Committee on Oceanography, it developed that one was not required at this time. Committees of this type require an Executive Order for their establishment, and are necessarily very high level. The experience has been that they are not very successful.

3. It was concluded that the functioning interagency informal Coordinating Committee on Oceanography (CCO) should be enlarged, and retained. In addition, another committee should be formed at the next higher level of government to include representatives who are involved with initial budget formulation. The new committee would meet once or twice a year to consider recommendations of the CCO.

4. It was agreed that the Department of the Navy would take the lead in requesting the establishment of the new committee. Accordingly, each agency was requested to suggest the names of possible members.

Operating within the framework of the FCST, the new mechanism established for interdepartmental cooperation is an *Interagency Committee on Oceanography* (ICO). The CCO was expected to continue to serve as an informal medium of communication, and in a staff capacity to the ICO. Significantly, however, representatives appointed to ICO are at sufficiently high levels of responsibility that decisions made by the group have a greater expectation of being implemented without the attenuating effect that is often present when the interagency decisions made at too low a level fail to meet the approval or endorsement and support of individual agency heads.

A clear exposition of the operation of the Interagency Committee on Oceanography was furnished by Assistant Secretary of the Navy James T. Wakelin in replying to questions of the House Committee on Science and Astronautics:

Q. (a) Could you describe present mechanism for interdepartment cooperation?

(b) Does the coordinating committee for oceanography control funds or exercise any line responsibility over oceanographic programs?

(c) Does it plan any Government-wide programs jointly and, if so, are copies of such a program available?

(d) Can you give examples of how the Committee coordinates requests for funds and uses of facilities?

A. (a) The Interagency Committee on Oceanography is a permanent mechanism of the Federal Council for Science and Technology with representation from the Department of Defense, Department of Commerce, Department of Interior, Department of Health, Education, and Welfare, National Science Foundation, and the Atomic Energy Commission. The purpose of the Interagency Committee is to implement, coordinate, and review the national program in oceanography. The Committee meets periodically to review the individual agency programs in the context of the national effort and to consider special problems that may arise in implementing the national program. The Committee has been enjoined by the Federal Council to consider other matters it deems relevant and important and to include additional agency representatives where this may be required or helpful.

It will engage in coordinated budget planning for fiscal year 1962. Of primary concern to the Committee is the development of a program which provides for reasonable increase in our national capability when faced with the critical limitations on scientific manpower, funds, and leadtime for the construction of ships and shore facilities.

(b) The Interagency Committee does not directly control funds nor exercise direct line responsibility over individual oceanographic projects. Each member of the Interagency Committee holds a position of policy and budget responsibility within his parent agency. The agency representatives were selected at this level to permit them to be able to commit their agencies in the coordination of the national program.

(c) *The Interagency Committee has not to date planned a Government-wide project or program.* [Emphasis added.] However, the Committee has established two working panels for specific purposes. The function of one panel is to plan and coordinate our ocean survey program. A second panel has the responsibility for working out details for planning and the policies for joint operation of a national data center. Additional panels are being considered—one for training and education, one for basic research, and possibly one for special devices and instrumentation.

(d) The development of the fiscal year 1961 budget required that the Interagency Committee review the individual programs and needs for funds of the principal Government agencies concerned with oceanography. The total funding requirements were presented to and endorsed by the Federal Council for Science and Technology concurrently with their submission in the President's budget. In the short time it has been established, the Committee has not had to consider coordination among the agencies of the use of facilities. In the development of the budget for fiscal year 1962, each agency's program and the national program as a whole will be reviewed critically by the Committee for balance and technical validity. *The Committee expects to seek endorsement of this consolidated program and budget from the Federal Council for Science and Technology and approval from the President before presenting it to Congress in the form of a package containing the complete national program in oceanography.*[72] [Emphasis added.]

It is perhaps significant that the field of oceanography is one of the very few singled out by the FCST for special emphasis and coordination. This response certainly reflects the importance that the executive branch attributes to the urgency. In part, it reflects a reaction to the special attention directed toward the matter of coordination by the Senate in its resolution 136, and the various pending bills.

The index of effectiveness of the ICO in coordinating interagency affairs must be actual accomplishment, but since this committee has been in existence only one year, it is certainly too soon for evaluation. That this committee has vitality appears widely recognized and applauded; and to a great extent, credit for its activities has been focused on the present chairman, James T. Wakelin. The fact that the present incumbent wears another hat as Assistant Secretary of the Navy for Research and Development puts him personally in a direct position to implement decisions as they may affect Navy budget requests.

A number of significant questions have been raised in Congressional hearings as to the ultimate stature and effectiveness of the ICO and its permanence as a medium of coordination. The ICO exists as an adjunct to the FCST, itself established as an advisory body to the President and without statutory basis. Its continuity may thus be jeopardized by the political winds which influence such bodies and their appointed members.

Alternate proposals by the Congress, by NASCO and by others for coordination are discussed subsequently. Suffice it to say, however, that agreement on the need for coordination is universal; differences of opinion develop only on methodology.

72 "Frontiers in Oceanic Research," op. cit., pp. 65–66.

G. U.S. PARTICIPATION IN INTERNATIONAL PROGRAMS

Details of the history and degree of participation of the United States in various international organizations concerned with the oceanic sciences are beyond the scope of this inventory. However, the reader may wish to become acquainted with those international bodies in which the United States is represented, or bound by bilateral or multilateral treaty. Brief background data are appended to reveal the scope and interests of these activities.[73]

1. Worldwide Scientific Organizations

These organizations are nongovernmental international bodies interested in oceanographic fields of science. The objects of such unions are (*a*) to promote the study of problems relating to their scientific fields; (*b*) to initiate, facilitate, and coordinate research into, and investigation of, those problems which require international cooperation; and (*c*) to provide for discussions, comparisons, and publications.

These bodies are usually sustained by the voluntary part-time work of a small group of devoted scientists elected for limited terms, whose enthusiasm and vitality are usually the greatest elements in their success.

(*a*) *International Council of Scientific Unions* (*ICSU*).—Organized in its present form in 1931 as the parent organization for a number of specialized scientific unions, ICSU was responsible for international coordination of the International Geophysical Year (IGY), its most ambitious and successful undertaking. The seven organizations which are described subsequently are affiliated with ICSU.

(*b*) *Special Committee for Oceanic Research* (*SCOR*).—SCOR was organized in August 1957 as a mechanism to extend international marine science activities of the IGY beyond its expiration in 1958. Major emphasis is placed on deep ocean measurements, theoretical studies of the dynamics of ocean circulation, studies of the Earth beneath the sea, protein food from the sea, and the role of the oceans in determining present, past, and future climates. One of SCOR's major projects now pending is a cooperative international study of the Indian Ocean, a project involving 16 ships from 11 participating countries over an interval of about two years.[74]

(*c*) *International Geophysical Cooperation, 1959* (*IGC–1959*).—This is a temporary organization for coordination of geophysical programs and data analysis after termination of IGY, including oceanographic observations made under IGY auspices.

(*d*) *International Union of Biological Sciences* (*IUBS*).—This organization has general interest in biology including that of the oceans.

(*e*) *International Union of Geodesy and Geophysics* (*IUGG*).—This large organization promotes studies of geographical problems, thus automatically including the oceans. Included within the IUGG are the International Association of Meteorology and Atmospheric Physics (IAMAP) and the International Association of Physical Oceanography, the latter devoted to such projects as production of standard samples of sea water.

[73] For more details, see "International and National Organization of Oceanographic Activities," an informal report of Richard C. Vetter prepared October 1959 for the Special Subcommittee on Oceanography of the House Merchant Marine and Fisheries Committee.

[74] Further implications of U.S. participation in this expedition are discussed in Section IV–C.

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(*f*) *Special Committee for Antarctic Research* (*SCAR*).—This organization is similar to SCOR in preserving continuity of IGY activities in the Antarctic.

2. Organizations Associated with the United Nations

(*a*) *Food and Agricultural Organization* (*FAO*).—This organization, interested in raising the nutrition and standards of living of peoples everywhere, sponsors conferences on utilization and development of fisheries, and has made a small number of fellowships available to students in marine sciences from underdeveloped countries.

(*b*) *International Atomic Energy Agency* (*IAEA*).—IAEA provides a mechanism for communication on problems in handling and disposal of radioactive wastes.

(*c*) *United Nations Educational Scientific and Cultural Organization* (*UNESCO*).—This important agency of the U.N. promotes collaboration among nations through programs in exchange of information, symposia, etc. The International Advisory Committee on Marine Sciences (IACOMS) is part of the natural sciences program of UNESCO: it encourages development of marine sciences in geographical areas where little has been done, and where benefits would accrue from increased supply of protein from the sea—mostly through fellowships and regional conferences and international symposia.

(*d*) *World Meteorological Organization* (*WMO*).—This agency encourages standardization of data collection, interpretation, and exchange of data and encourages research, particularly in matters of water resources.

3. Other International Organizations Interested in Oceanography

(*a*) *International Hydrographic Bureau* (*IHB*)—standardizes nautical charts and arranges for worldwide exchange of hydrographic information.

(*b*) *International Council for the Exploration of the Sea* (*ICES*)—is the oldest international oceanographic organization, devoted to promotion of cooperation of member governments particularly for fishery management. This organization is said to have a strong history of success with international agreements even in environments laden with strong national feelings.

(*c*) *International Ice Patrol* (*IIP*)—organized in 1914 by treaty to improve safety of navigation in the vicinity of the Grand Banks; makes oceanographic observations during the iceberg season.

(*d*) *North Atlantic Treaty Organization* (*NATO*)—In carrying out its charter, dedicated to collective defense of member nations, NATO has a working group on ocean shipping that includes a Subcommittee on Oceanography. It is also sponsoring an oceanic research laboratory at La Spezia, Italy.

(*e*) *Pan American Institute of Geography and History*—through a committee on oceanography of the oceans, this group has prepared technical background for studies of the oceans by the Organization of American States, and the Inter-American Economic and Social Council.

(*f*) *Pacific Science Association*—is a private international (regional) organization of scientists interested in problems of the Pacific Ocean.

4. International Commission for Study and Protection of Fisheries

(*a*) *International Whaling Commission* (*IWC*)—established under the International Whaling Convention of 1948, this agency is devoted to conservation of the world whale sources; it encourages studies and research on whales, collects statistical information on whale populations, etc.

(*b*) *International Commission for the Northwest Atlantic Fisheries* (*ICNAF*)—established as a result of an international convention of 1949 to protect and conserve fisheries in the cognizant region through investigations, regulation and proposed programs of research.

(*c*) *Eastern Pacific Oceanic Conference* (*EPOC*)—is an informal group of scientists concerned mainly with regional interests.

(*d*) *Inter-American Tropical Tuna Commission* (*IATTC*)—established by treaty with Costa Rica in 1950, this commission has a broad program of research on tuna of the East Pacific, including abundance, ecology, etc. IATTC also develops bases for any future regulation of the industry.

(*e*) *International North Pacific Fisheries Commission* (*INPFC*)—established by treaty in 1952 to coordinate programs of research concerned with regional interests in tuna.

(*f*) *International Pacific Halibut Commission* (*IPHC*)—established by convention to study and, if necessary, regulate fishing for halibut.

(*g*) *International Pacific Salmon Fisheries Commission.*

(*h*) *North Pacific Fur Seal Commission.*

The length of this list of international organizations having interests in the sea reveals the broad geographical as well as subject matter content of such programs. It is also strongly indicative of the interest and cooperation as well as initiative of the United States in fostering cooperative and inter-government organizations whenever the problems suggest this form of solution.

The large number of different organizations also represents the recent phenomenon of proliferating international agencies which have grown spontaneously to fill the gaps produced during World War II in international communication. Questions of the benefit to be gained by consolidating certain of these activities are beyond the scope of this present report. However, as a matter of conserving and best utilizing the efforts of American oceanographers who participate in these organizations, the Department of State, in concert with the scientific community and cognizant government agencies, will be confronted with decisions on how these various groups best fit any emerging plans for increased activities in oceanic research, particularly insofar as future international cooperation and coordination are concerned.

H. COMPARISON OF OCEANOGRAPHY IN THE UNITED STATES AND U.S.S.R.

A comprehensive study of the respective oceanographic programs of these two nations is an essential step in planning any long range strategy for a national program of oceanographic research—not simply to extend what appears to be a "fad," but because the matter of competition with the Soviets in and for the sea is one of the significant elements that threatens national security. Consequently, to provide perspective when analyzing sufficiency of the present U.S. program, facts concerning contemporary Soviet efforts are reviewed briefly, particularly to bring into focus any evidence of trends.

Two different discussions follow, each from separate sources that appear consistent in their recitation of Soviet statistics.

Laboratories

According to a published review of work by the principal coordinating body for oceanography in the U.S.S.R., the Oceanographic Commission of the Academy of Sciences, marine subjects are being investigated at nearly 100 establishments which are subordinate to 16 ministries and agencies. However, of all these establishments only a few are conducting significant research. The leading oceanographic research institutions are the Institute of Oceanology of the Academy of Sciences, the Marine Hydrophysics Institute of the Academy of Sciences, the State Oceanographic Institute of the Main Administration of the Hydrometeorological Service, the Arctic and Antarctic Scientific Research Institute of the Main Administration of the Northern Sea Route, and the All-Union Scientific Research Institute of Fish Economy and Oceanography.

The Institute of Oceanology, Academy of Sciences, U.S.S.R.—This institute is responsible for the complex study of the seas and oceans. Founded in 1946 from the Laboratory of Oceanology, the institute is subordinate to the Department of Geological and Geographic Sciences of the Academy of Sciences, U.S.S.R. The institute, under the direction of V. G. Kort, is located at Luzhnikovskaya ulitsa 8, Moscow. It also maintains stations near Baku on Artema Island in the Caspian Sea and near Gelendzhik on the coast of the Black Sea. The staff of the institute numbers more than 500 and includes about 120 scientists. The research fleet of the institute includes the *Vityaz, Geolog, Akademik Vavilov,* and *Akademik Shershov.*

The institute is responsible for the study of the physical, chemical, geological, and biological characteristics and processes occurring in the oceans. It is also responsible for the study of the water level of the Caspian Sea, the scientific development of new methods, and the design of new instrumentation for oceanographic research. The scientific activities and accomplishments of the institute are reported in the *Trudy Institute Okeanologii Akademii Nauk, S.S.S.R.*

The Marine Hydrophysics Institute, Academy of Sciences, U.S.S.R.—This institute was organized in 1948 by combining the Black Sea Hydrophysics Station at Katsiveli in the Crimea and the Marine Hydrophysics Laboratory in Moscow. It is subordinate to the Department of Physico-Mathematical Sciences of the Academy of Sciences, U.S.S.R. The acting director is V. I. Grabovsky. The main institute is located at Sadovaya ulitsa, Lyublino, Moscow, and the Black Sea Station is near Simeiz, Katsiveli, Crimea. The facilities of the institute include a wave basin and the recently acquired research vessel *Mikhail Lomonosov.*

The institute is responsible for the study of physical and dynamic oceanography. Work is conducted on wave research, the thermal regime of the sea, and the interaction of oceans and continents. Many of the results are published in the journal of the institute, *Trudy, Morskovo Gidrofizicheskovo Instituta.*

The State Oceanographic Institute.—Formed in 1943, this institute is the central organization for oceanographic and marine hydrometeorological research under the Main Administration of the Hydrometeorological Service. The main institute under the direc-

tion of A. A. Yushchak is located at Kropotkinskiy perevlok dom 6, Moscow. There is also a Leningrad branch under the direction of Yu. V. Preobrazhenskiy and a laboratory on the Caspian Sea. The staffs number approximately 200 at the Moscow institute and 100 at Leningrad Branch. The facilities of the institute include the research vessels *Professor Rudovits* and *Okeanograf* and a 32-component Doodson tide machine.

The institute is principally concerned with the waters immediately adjacent to the U.S.S.R. The research is undertaken as support to economic activities such as the fishing industry, the merchant marine, and the oil industry. It is concerned with theoretical investigations and the development of new methods, mainly in physical and dynamic oceanography. Besides conducting research, the institute also publishes books and tables, supervises the scientific programs of a network of marine hydrometeorological stations, prepares oceanographic forecasts, and develops new instrumentation. Much of the research work is published in the journal of the institute, *Trudy, Gosudarstvennyy Okeanograficheskiy Institut.*

The Arctic and Antarctic Scientific Research Institute.—There is a Department of Oceanology within this institute and it is concerned with the oceanography of the Arctic and Antarctic areas and with ice forecasting for the Main Administration of the Northern Sea Route. The institute is located at Fontanka 34, Leningrad, and is under the direction of V. Frolov. Its Department of Oceanology with a staff of 125 to 150 is under A. F. Laktionov. There is also a small laboratory in Moscow maintained for routine chemical, physical, and geological analysis and for the production of "normal sea water." Oceanographic research by the institute has been conducted aboard the *Ob'*, *Lena*, *Fedor Litke*, *Biu*, *Aktyubinsk*, *Toros*, *Polyarnik*, and *Lomonosov.*

The Department of Oceanology is concerned with all aspects of oceanography of the polar regions, including the study of sea ice. It is also responsible for observing and predicting sea ice and its movement. Members of the department participate in shipboard, airborne, and drift station expeditions in support of this research. The institute publication *Problemy Arktiki* reports much of the results from the oceanographic research.

All-Union Scientific Research Institute of Fish Economy and Oceanography.—The institute was organized in 1933 by the combination of the All-Union Scientific Research Institute of Marine Fisheries and the State Oceanographic Institute. In 1943 the State Oceanographic Institute again separated leaving the present organization. The main institute under the direction of G. K. Izhveskiy is located in Moscow and is subordinate to the Ministry of Fish Industry. This institute also has regional affiliates—in Murmansk, the Polar Scientific Research Institute of Fish Economy and Oceanography; in Kaliningrad, the Baltic Scientific Research Institute of Fish Economy and Oceanography; and in the Far East, the Pacific Ocean Scientific Research Institute of Fisheries and Oceanography.

The institute and its affiliates are concerned with oceanography in support to fisheries and basically with the ecological aspects. Consequently, the institute is active in routine oceanographic surveys both in support of existing fishing areas and in the development of

new ones. In support of its research activities, the main institute has been assigned a submarine undergoing conversion for oceanographic research.

Manpower

A review of the two principal Soviet journals abstracting oceanographic articles indicates that approximately 500 Soviet scientists and technicians have authored articles in the field of oceanography subsequent to 1954. The distribution of these individuals by specialty is shown in the following table:

Distribution of Soviet authors by specialty (1955)

Physical and Dynamic Oceanography:	
General	78
Circulation and Currents	55
Thermal Structure, Balance, and Processes	56
Tides, Seiches, and Sea Level	41
Waves and Tsunamis	77
Total	307
Chemical Oceanography	36
Submarine Geology	65
Instrumentation and Methodology	37
Polar Oceanography and Ice Studies	50
Hydrometeorology (Oceanographic Forecasting)	27
Total	522

The total of 522 is assumed to include many technicians who were junior authors of published articles. Furthermore, many of the authors have but a single contribution and are better known in other scientific disciplines. Nevertheless, the estimate of approximately 500 oceanographers in the U.S.S.R. based on published scientific papers agrees satisfactorily with known and estimated manpower assignments of the leading oceanographic research facilities, the figures for which are shown in the following table:

Manpower at Soviet oceanographic institutions

	Total staff	Scientists	D. Sc.'s and Ph. D.'s
Institute of Oceanology	(1)	120	22
State Oceanographic Institute:			
Moscow	200	97	47
Leningrad	100	[2] 50	
Arctic and Antarctic Scientific Research Institute:			
Leningrad	135	[2] 100	20
Moscow	48		
Marine Hydrophysics Institute		[2] 50–100	
All-Union Scientific Research Institute of Fishing Economy and Oceanography (including all regional affiliates)		[2] 100	

[1] 500-plus. [2] Estimated.

The estimations in the table are based on the relative research activities with respect to known institutes and also responsibilities for oceanographic research.

Research vessels

The research fleet of the U.S.S.R. probably numbers between 50 and 75 nonmilitary vessels with lengths greater than 50 feet. None of these vessels, including the new *Mikhail Lomonosov,* was designed and constructed for oceanographic research. Rather, they are modified sailing, fishing, icebreaker, and cargo types. The most modern and capable Soviet vessels are the *Vityaz* and *Mikhail Lomonosov.* These together with the *Ob'* and *Lena* give the U.S.S.R. at least one vessel of greater than 5,000 ton displacement in the Atlantic Ocean, Pacific Ocean, Arctic and Antarctic waters, respectively. The first submarine in the world to be used solely for oceanographic research, *Severyanka,* is now operating and adds another unique feature to the Soviet research fleet.

The larger vessels are capable of engaging in all phases of modern deep-sea oceanographic research. They have numerous laboratories and can accommodate scientific parties of more than 25 persons. The *Vityaz* and *Mikhail Lomonosov* can accommodate from 60 to 70 persons for research. Several of the larger offshore vessels, however, are used for other duties in addition to scientific research, such as training cadets and serving as logistic supply ships. Including these, the offshore fleet has at least 12 vessels with lengths greater than 200 feet and also at least 5 vessels capable of operating in moderate ice conditions.

The coastal research fleet of vessels under 125 feet in length is comprised mostly of converted fishing boats. This group of vessels can also be supplemented by a group of converted medium-class fishing trawlers and three-masted sailing vessels from the offshore fleet.

A separate appraisal by the U.S. Navy was recently offered to the House Science and Astronautics Committee: [75]

> The U.S. oceanographic capability can be measured in number of ships, scientists, and dollar support. At the present we operate about 52 ships and have about 500 to 600 professional oceanographers. The fiscal year 1961 budget for oceanography exclusive of ship construction is $36.6 million. By 1970 we expect to have increased the number of our oceanographic ships to about 85 or 90 and to have engaged about 1,100 or 1,200 competent scientists in oceanography. It can be expected that the costs for conduct of oceanographic research and surveys by 1970 will level off at approximately $85 million annually.
>
> Although receiving greater emphasis since World War II, oceanography has undergone a marked expansion in the Soviet Union since 1955, following the announcement of its plans to participate in the oceanography program of the International Geophysical Year (1957–58). Therefore, Soviet oceanographic research was limited mostly to the regions bordering upon the U.S.S.R., and scientific relations with foreign scientists were essentially nonexistent. Since 1955, the U.S.S.R. has displayed a large modern research fleet second to none, has announced the construction of new research facilities, has operated its research fleet throughout the oceans of the world, and has organized a sizable manpower force to conduct oceanographic research. The period from 1955 to 1960 definitely has been one of acquiring facilities, manpower, and scientific data.
>
> The Soviet oceanography program has been a survey effort to collect oceanographic observations of all types over broad geographic areas. * * * The present research fleet of the Soviet Union to support this type of effort is comprised of a large number and variety of ship types ranging from small fishing vessels to the *Mikhail Lomonosov* (5,960 tons). It also includes the research submarine *Severyanka.* New vessels have been acquired almost annually for this fleet. Since 1957, the *Mikhail Lomonosov,* 5,960 tons; the *Severyanka,* 1,050 tons; the

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[75] The preceding material was extracted from unpublished information compiled by NASCO in 1957–58 That following was furnished by Secretary James T. Wakelin, "Frontiers in Oceanic Research," op. cit., pp. 53–54.

Voyeykov, 3,600 tons; and the *Shokal'skiy*, 3,600 tons, have been added. The rate at which new ships are being acquired probably will continue for the next several years. Other converted submarines for research and underwater research vehicles, such as bathyspheres and bathyscaphs, also are expected to be acquired and supplement the surface research fleet within the next few years. Soviet plans to construct a bathyscaph were announced earlier this year and bathyspheres have been used for several years.

Shore-based facilities also have been expanded and constructed during the past several years, mostly located in the Moscow area. However, plans to construct scientific bases for two oceanographic institutes were announced in 1958 and a branch of the Marine Hydrophysics Institute was opened recently in Kaliningrad on the Baltic Sea. Considering the distance from Moscow, and the Soviet effort that has been expended in the Pacific Ocean and bordering seas, the expansion and construction of facilities should be expected in the Far East during the next several years.

The number of Soviet oceanographers, excluding marine biologists and fisheries researchers, is greater than 500. The total of their professional oceanographers is estimated as high as 800 to 900. The greatest expansion of manpower probably took place when the Soviet Union expanded its program to participate in the International Geophysical Year. Many of the oceanographers are young and lack experience, a partial explanation for the placing of the great numbers of scientific personnel on the large ocean research ships. However, the quality of these young scientists should improve from the experience being gained from present shipboard research and the analyses of data collected since the International Geophysical Year. It seems that quality rather than quantity of scientists is now needed in the Soviet Union.

The present research effort is oriented toward applications. Even the basic research conducted at the institutes of the Academy of Sciences tends to be directed toward ultimate applications. The institutes subordinate to ministries direct their research to support the efforts of the parent organizations. Polar and deep sea oceanographic research are the strongest areas in the Soviet program. Continued and intensive scientific activity in arctic regions to develop the Northern Sea Route has achieved a leading position in arctic oceanography for the Soviet Union; and the operations of the research fleet throughout the oceans of the world have shown an impressive ability to collect oceanographic data. High quality work also has been conducted in biology and fisheries research, marine geology, and seismology, particularly in conjunction with deep sea research. The work in other areas of oceanographic research generally has not been of comparable quality. There is no information available concerning their military research efforts in oceanography. As the oceanographers gain experience, the quality of the research should generally improve within the next several years.

It is generally conceded that the present size and the rate of expansion of the Soviet manpower and ships for oceanographic research are considerably greater than those of the United States, and possibly of the entire free world. Their oceanographic research, rated as excellent in some fields of the science, is generally not as scientifically comprehensive as that of the United States. During the IGY their effort consisted of a well-rounded, exploratory-type program to collect basic information about the characteristics of the seas and oceans of the world. It did much to increase the stature of the U.S.S.R. among the world leaders in oceanography as well as to provide scientific support for the Soviet economic and political aspirations.

Much has been written concerning the relative size and strength of national programs in scientific research as between the United States and the U.S.S.R., and conclusions regarding the two programs are familiar to the reader. Insofar as the special field of oceanography is concerned, numbers of participants and size of research ships reveal only the more obvious characteristics of a program.

On the basis of the statistics just presented, however, it is apparent that oceanography in Soviet Russia is not neglected. Moreover, it can be supposed that, in a country that closely controls its assignment of scientific manpower, the enlargement of this program is deliberate,

planned, and fostered by explicit, even if not published, government policy.

Past experience in these matters, particularly in the case of Soviet achievement in outer space, has revealed a pattern to such moves—namely, specific practical application which will serve the aggressive intentions of the Soviets, either by military or nonmilitary means.

The question of how the U.S. effort stands in relation to the Soviet is thus of some interest. Perhaps the generally accepted view is best summarized by a recent statement by Dr. Harrison Brown, who chairs the Committee on Oceanography of the National Academy of Sciences:

> Mr. FULTON. Would you comment now on the advance the Russians are making in this same field as compared to our U.S. advance? For example, they have the Russian oceanographic ship, *Vityaz.* They also have the *Lomonosov,* the new one. Are we keeping pace in the type of equipment and the type of work they are doing?
>
> Dr. BROWN. I believe that we have to keep in mind when we talk about Russian activity in this area, that they started intensive efforts in oceanography only quite recently.
>
> I am told by my friends who have studied the situation that in effect what they are doing now on a large scale is training young oceanographers. They suffer from the same kind of problem from which we suffer and that is inadequate trained manpower in the field.
>
> Their large ships are being used in part as training ships for young people in oceanography.
>
> Now, on the basis of what I have read and on the basis of what I have learned from talking with Russian oceanographers, as well as with oceanographers from other countries who have studied what the Russians are doing, my best guess would be that the rate of improvement in the Soviet Union in this respect is considerably greater than the rate of improvement in the United States.
>
> Now, this doesn't mean that they are ahead of us at the present time, but the curves are likely to cross.[77]

The same appraisal has been made by Gordon G. Lill, formerly head of the Geophysics Branch of the Office of Naval Research:

> The Russians successfully completed, during the International Geophysical Year, the largest program of any nation, and there were 27 countries participating, in oceanography. * * *We are not too alarmed at this unfavorable comparison when we consider that our work in the marine sciences is generally conceded to be of higher quality than that of the Russians. The point is that the Russians have decided to compete in oceanography and that they are competing very well. Their scientists are well trained. With a few years of experience at handling huge quantities of data, they will be as good at it as we are and the size of their effort would automatically place them in the lead. *The Russians are in oceanography for obvious military and economic reasons and it appears to be their objective to stay in and to excel.*[78] [Emphasis added.]

[77] "Frontiers in Oceanic Research," op. cit., p. 17.
[78] "Oceanography in the U.S.", op. cit., p. 188.

VII. Summary and Analysis of U.S. Programs in Oceanic Research

Statements by a number of national leaders have been summarized showing the vital relationship of oceanic research to national security. Specifics have been added, by way of example, indicating possible directions that such programs of research might take in development of basic knowledge about the oceans, and in ultimate application for both military and peaceful purposes. Existing programs have been inventoried in terms of organizations, manpower, facilities, funding and government sponsorship.

The question thus arises as to whether the existing program matches the needs. To assist the reader in arriving at conclusions in this regard, the previously cited rationale for research, and statistics concerning the present U.S. posture have been distilled and summarized.

A. THE SCIENTIFIC PROGRAM

1. Detailed knowledge and understanding of the oceans and of their contents appears almost completely lacking, particularly in comparison to continental areas of the planet Earth. Because the seas are largely unexplored, there is a greater statistical likelihood of a "scientific breakthrough"; scientists, Government officials and informed opinion suggest that research in this field thus offers unusually rich promise to sponsors and investigators alike in terms of potential scientific and geographic discoveries and in their application.

2. Thus research in the oceans, apart from being motivated by human curiosity and the search for learning, has the strong possibility of directly and significantly affecting political, economic, and military affairs. A major element of our national security policy of deterrence already depends on mobility and concealment within the sea of missile-launching Polaris submarines. Survival also clearly depends on adequate surveillance of the oceans to minimize a surprise attack from off our shores. In terms of peaceful application keyed to a balanced program of national security, the oceans may heavily supplement human nourishment in an era of burgeoning population, may provide new mineral resources in a day of continental depletion, and may provide the key to understanding weather and climate as a logical step to its control. Study of the seas may reveal the origin of our planet, the origin of life on it, and the dynamic processes of change.

3. Although oceanography as the science of the seas is descriptive of one part of the world around us, it is an inter- or multi-disciplinary science, involving application of fundamentals from physics, chemistry, geology, and biology.

4. The ingredients of an oceanographic program can be measured quantitatively in terms of manpower and its organization, facilities, and funds. Far more difficult is its appraisal in qualitative terms which reflect such intangibles as scientific accomplishment and utilization of manpower.

5. Research programs are often characterized by the proportion of basic research necessary to refresh the general fund of knowledge from which applications are made. A fairly substantial proportion of funds appear to be available for basic, undirected research. Nevertheless, most laboratories are obliged to conduct mixed programs wherein the applied research is accepted as a means of fiscal solvency. Schedules of research vessels may be so affected to accommodate applied programs that the proportion of funds available for basic research may not be a reliable indicator of the amount of basic research that is being accomplished.

6. Because the Federal Government is a dominant sponsor of research in the sea, the programs heavily reflect responsibilities of the particular Government agencies administering the programs.

7. Although extensive inventories have been made of the Navy's contract research program in oceanography, its "inhouse" program and capabilities have not been studied or integrated, possibly because many of these have until recently been heavily developmental or nonexistent.

B. MANPOWER

1. The total number of senior and junior scientists participating in ocean research was estimated in 1958 to be less than 1,600. In view of the subject matter and geographical scope of this field, these scientists must be thinly spread.

2. Fewer than 600 U.S. senior scientists are engaged in some phase of oceanic research on a full-time basis. This segment represents less than two-tenths percent of the estimated 300,000 professionally qualified persons having project-leader responsibilities for research and development in this country.

3. The size and scope of the existing national program is thus sharply limited by this small number of participants. Moreover, any expansion in rate of effort will continue to be critically keyed to the availability of trained manpower.

4. Because of its being a derivative rather than basic scientific discipline, oceanography can draw manpower from other fields, such as physics, chemistry, biology, etc. In fact, specifically trained oceanographers may represent only about one-eighth of the total number of participants, others coming from the aforementioned fields, and mixed fields of geochemistry, geophysics, biophysics, meteorology as well as from many branches of engineering.

5. Additions in manpower may be developed from two sources: transfer of scientists from other relevant fields, and training of increasing numbers of students whose career goals are focused on oceanic research. Gains by training students are preferred so as not to drain off persons from other fields also suffering manpower shortages.

6. The Ph. D. content of scientists in oceanic research is higher than most other fields, which raises the question as to whether greater numbers of personnel with less formal training, and even technicians, might be profitably employed.

7. Although salary data were not directly available, there is the strong suggestion that financial compensation in oceanography is relatively low. There may thus be some difficulty in recruiting personnel from the basic sciences, in competition with other fields, such as research in outer space in which salaries have advanced faster.

Compensation incentives for graduate students may be similarly lacking.

8. Studies have not been conducted to determine means for improved utilization of existing staffs.

C. ORGANIZATIONS CONDUCTING RESEACBH

1. Basic and applied oceanography, in terms of reference of this report, is conducted primarily in universities and nonprofit laboratories. To a lesser degree, some research is conducted in Government-owned and operated laboratories; but virtually none is considered as conducted by private industry. That concerned with proprietary developments such as seismic surveys for offshore oil exploration have not been included because data are not publicly available. Studies concerned with submarine cable laying, while extensive, are regarded primarily as developmental.

2. Many of the non-Government organizations conducting research were established as independent laboratories. However, because Government sponsorship now so strongly dominates their program, there is a question as to the degree with which they can remain independent, without evolving to the status of a creature of the sponsor.

3. Roughly 70 separate organizations are engaged in oceanic research. Apart from some 16 or so large units, the field is characterized by a large number of small laboratories which primarily cater to local interests in marine biology or to instruction. Over half of the laboratories employ less than 10 full-time staff, and lack modern facilities and instruments.

4. Although the smaller organizations exist in large number, facilities and manpower are so limited that even collectively, they could not be expected to carry the main burden of any national program. Nevertheless, with the high degree of communication and coordination that exists among participating scientists, cooperative programs have been employed in the past wherein staff of smaller laboratories are given an opportunity to share space and facilities on research ships attached to the larger laboratories. This type of endeavor may be expected to increase.

5. The smaller university groups can make a sizeable contribution to teaching of new students.

D. FACILITIES AND SHIPS

1. Oceanography differs from most other sciences in requiring extensive facilities for the conduct of research—in the form of ships and seagoing vehicles. Thus, amortization costs of capital equipment and operating costs of facilities are disproportionately high, representing perhaps 40 or more percent of the total costs during normal operations. In this regard, it is comparable to research in outer space.

2. There are now 32 ships owned and operated by U.S. laboratories for purposes of oceanographic research and 18 for hydrographic surveying. In the aggregate, the research ships displace 21,498 tons; the survey ships, 57,308 tons.

3. Most of these ships are over 15 years old; their average age is 18 years.

4. All but one of these ships were converted from some other original purpose, and by not being specifically designed for ocean research, they carry a ratio of crew-to-scientist of 3 to 1 up to 10 to 1, instead of an optimum 1 to 1. Some of the survey ships, although far larger than required for this function, collaterally serve to train naval crew.

5. Because these ships are not well suited to their present function, operating costs may be excessive. Their replacement by properly designed vessels would not only reduce these operating costs, but would increase the effectiveness of scientific manpower who must put in a substantial portion of their research time at sea. An improvement in effectiveness of 30 percent, for example, is equivalent to an increase in professional staff of that same amount.

6. Since the present fleet appears to be fully utilized, any marked expansion in oceanographic research can be satisfied only by a comparable increase in the number of vessels. Because of the long lead time for planning, designing, and building such ships, funding must anticipate actual service by 2 to 3 years. The proportion of budget devoted to ships will be more during intervals of capital expansion—even possibly exceeding 50 percent of total appropriations.

7. Any expansion in program, with corresponding needs for manpower and facilities, should be phased to avoid the losses of a crash program. Funds should thus be available for facilities in an orderly relationship to demands for expansion in program and of the corresponding increases in manpower.

8. Further research in the ocean now requires a whole new generation of vehicles capable of putting instruments and men deep within the environment itself—for the systematic and selective probing of the sea and its contents. The U.S. Navy's bathyscaph represents a first step, and world leadership in this important field. Until other vehicles following the *Aluminaut* concept are available, it represents the only U.S. capability for exploring the deep ocean.

9. Provisions are lacking for central storage, coordination and retrieval of survey data.

10. No inventory has been made of availability or specific future needs of shore-based facilities, as has been done for ships, except by TENOC for those laboratories operating on Navy contracts.

E. FUNDING

1. The most recent comprehensive statistics on a national basis are for fiscal year 1958. At that time, a total of $30 million was devoted to oceanic research of which $24.1 million was contributed by Federal agencies. The largest single sponsor was the Navy, whose contributions of $13.71 million represents 46 percent of the national total.

2. In 1958, Federal sponsorship of oceanic research represented slightly more than 2 percent of the total Federal funds obligated that year for all research (exclusive of development).

3. For Fiscal 1959, Federal funds allocated to oceanographic research, exclusive of those development projects with specific military objectives, again totaled roughly $18 million. For Fiscal 1960, the total has been increased to $39 million, with most of the increase from the Navy.

4. The proposed Fiscal 1961 budget of $55 million, representing still further growth in oceanic research, is 6 percent of the $950 million proposed to be devoted to nonmilitary research in outer space.

5. The National Science Foundation has initiated a small program in oceanography and has funded a new research ship. In general, however, relatively limited increases in support for oceanographic research have developed from the civilian component of Federal sources, or from non-Federal sources.

6. Commercial payoff of research in the sea is apparently considered so marginal by industrial interests that, to date, virtually no risk capital has been attracted. Nevertheless, the number of industrial engineering ventures in the sea is increasing. As this undersea activity expands further, industry will have increasing need for basic information about the sea.

7. Nonprofit, independent organizations originally endowed for research in oceanography now depend largely on Government contracts rather than interest from their investments as a source of operating capital. Virtually no new endowments have been developed in the last 30 years. Recommendations by the 1949–51 NAS Committee on Oceanography for increased private support did not produce the response that a similar study produced in 1927–29.

F. STATUS OF A NATIONAL PROGRAM

1. As in the case of atomic energy and outer space, research in the oceans is dominated by Federal sponsorship.

2. At present, some 19 different Government departments have responsibilities, and in some measure, support programs in oceanography. By far the greatest support, however, is derived from the Office of Naval Research. Other major sponsors include: Bureau of Commercial Fisheries, Coast and Geodetic Survey, Atomic Energy Commission, and the National Science Foundation.

3. Some overlap occurs between responsibilities of different agencies as, for example, in the sponsorship of basic research between the National Science Foundation and the Office of Naval Research; for surveys, between the U.S. Navy Hydrographic Office and the Coast and Geodetic Survey; for control of radioactive waste, between the Atomic Energy Commission and the Public Health Service.

4. Interdepartmental coordination has been effected informally since 1956 through the Coordinating Committee on Oceanography organized by the Office of Naval Research, and is now effected through the Interagency Committee on Oceanography of the Federal Council for Science and Technology, with Assistant Secretary of the Navy Wakelin serving as chairman. However, no formal charter or statutory basis exists for this coordinating function. The short time of operation of the ICO precludes evaluation of its effectiveness.

5. Although several clear statements of purpose and long-range programs in oceanography have been proposed, none has been adopted as national policy.

6. Inasmuch as oceanography has one major sponsor, the Federal Government, a national program can be more readily constructed, and more fluently coordinated, than if the sponsorship were more diversified.

7. Leadership and support at the Department level for nonmilitary aspects of oceanographic research are not as clearly evident as in the case of the Navy. At present, this responsibility is fragmented.

8. The United States now maintains a position of international leadership in a number of sectors of research in the ocean. It is visibly ahead in the area of manned vehicles for the exploration of the deep ocean. Logistic support for work in the deep ocean has been reported as deficient.

9. Oceanography is one area of Soviet science gaining government support and although their history of research in the oceans is relatively short, they show signs of overtaking the United States very quickly. Soviet leadership in study of the Arctic areas is already acknowledged. United States retention of a position of world leadership is not assured by current rate of activity, even considering some element of growth; if we fall behind, "catching up" in this field would be almost impossible because of the problems in manpower.

10. A large number of international organizations now cater to interests in oceanography, some representing the scientific community, some the United Nations, some especially constructed to assist in the preservation of fisheries, and some serving miscellaneous regional and international needs. The United States is participating in virtually all of these, through contributions of funds as well as service.

VIII. Future Programs

Since 1957, three significant studies have been undertaken to lay the groundwork for a systematic and coordinated long-range program in oceanography.

The three studies embrace (*a*) a comprehensive analysis by a newly formed third Committee on Oceanography in the National Academy of Sciences, National Research Council (NASCO), undertaken at the request of several Government agencies; (*b*) a parallel study by the Office of Naval Research but only concerned with the Navy's contract program in Oceanography (TENOC); and (*c*) studies of the previous two programs by interdepartmental bodies, in particular, the Interagency Committee on Oceanography (ICO). Additional studies, yet unreported, are being made by ONR to supplement item (*b*) with information regarding the Navy's own inhouse program of oceanographic research which has not been included in the original TENOC program.

All three studies have developed subsidiary benefits. For the first time a national inventory of manpower, ships, and of funding became available, and much use has been made of these facts in foregoing sections. Second, as with other activities, the mere process of study has subtle but nevertheless telling effects on the subject being studied. There is some likelihood that the mere act of appraisal has produced significant feedback so as to elicit stocktaking by those undertaking management of oceanographic programs, those sponsoring programs, and those having statutory responsibilities. Third and most important, these studies provide valuable guidance for a coordinated long-range program in oceanic research. Details remain to be worked out by the operating agencies, but a frame of reference now exists against which program content and rate of progress can be tested.

A. Proposals of the National Academy of Sciences, Committee on Oceanography (NASCO)

In 1957, a number of Federal agencies having responsibilities in Oceanography, and aware of the growing need for a coordinated national program, requested the National Academy of Sciences—National Research Council (NAS–NRC) to form a new Committee on Oceanography to advise the Government on the needs for research, on the present status of activity within the United States, and to propose a program that would serve as a basis for orderly planning in the future.

In fulfilling its traditional role as a consultant to the Government in affairs of science and technology, the National Academy of Sciences—National Research Council had twice before formed similar committees concerned with Oceanography—the first was established in 1927 under the chairmanship of Dr. Frank R. Lillie, and the second, in 1949, under Dr. Detlev W. Bronk. These earlier studies had various de-

grees of impact, but the fact that oceanography has not developed without such outside stimulation is a special point deserving of study.

This most recent request, formulated by the Office of Naval Research in conjunction with the U.S. Fish and Wildlife Service, the Atomic Energy Commission, and the National Science Foundation, was transmitted to the NAS–NRC by the Chief of Naval Research and received an immediate favorable reply from Dr. Bronk, now President of the Academy. A Committee of ten was appointed, with Dr. Harrison S. Brown, Professor of Geochemistry at the California Institute of Technology, as chairman. The other members included:

Maurice Ewing, director, Lamont Geological Observatory, Columbia University; Columbus O'D. Iselin, retired director, Woods Hole Oceanographic Institution; Fritz Koczy, professor at the Marine Laboratories, University of Miami; Sumner Pike, Lubec, Maine, formerly Commissioner, U.S. Atomic Energy Commission; Colin Pittendrigh, professor of biology, Princeton University; Roger Revelle, director, Scripps Institution of Oceanographic Laboratory, Yale University; Milner B. Schaefer, director, Inter-American Tropical Tuna Commission; and Athelstan Spilhaus, dean of the Institute of Technology, University of Minnesota.

Mr. Richard Vetter, formerly of the Office of Naval Research, was made Executive Secretary.

The investigation was then undertaken over a period of about 1 year by the members of the Committee on Oceanography, as a part-time endeavor while on periodic intervals of leave from their main post, supplemented by five panels of specialists who contributed to the program similarly.

A summary report of the Committee was released by the NAS–NRC on February 15, 1959: Chapter 1—"Oceanography, 1960–70." Eleven supplementary documents are planned, to amplify the basic study and the recommendations as follows:

Chapter 2. Basic research in oceanography during the next 10 years
Chapter 3. Ocean resources
Chapter 4. Oceanographic research for defense applications [79]
Chapter 5. Artificial radioactivity in the marine environment
Chapter 6. New research ships
Chapter 7. Engineering needs for ocean exploration
Chapter 8. Education and manpower
Chapter 9. Oceanwide surveys [79]
Chapter 10. International cooperation
Chapter 11. History of oceanography [79]
Chapter 12. Marine sciences in the United States

On the basis of its findings, the Committee drew up a series of recommendations which the members felt would strengthen the marine sciences during the next 10 years to a level consistent on the one hand with the assessed urgent needs, and on the other hand, with certain inherent limitations such as the rates at which ships and laboratories can be built and new oceanographers trained.

The Committee stressed, however, that its recommendations were minimal. They went on to say:

Action on a scale appreciably less than that recommended will jeopardize the position of oceanography in the United States relative to the position of the science in other major nations, thereby accentuating the serious military and political dangers, and placing the nation at a disadvantage in the future use of the resources of the sea.[80]

[79] These three chapters are still in preparation.
[80] "Oceanography 1960–70; Introduction and Summary of Recommendations," NASCO Report. Ch. 1, p. 2.

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The Committee found that relative to other areas of scientific endeavor, progress in the marine sciences in the United States has been slow, especially considering the challenge that the seas present which they contend is every bit as significant in our national life as is outer space.

Particular attention was drawn to all of the military and nonmilitary potential of the sea noted earlier in this report, finally concluding with a set of five recommendations. These are reproduced in the following:

The key to the growth of oceanography in the United States lies in basic research—research which is done for its own sake without thought of specific practical applications. The very nature of basic research is such that the problem which will be attacked and the results which will be obtained cannot be predicted. The very nature of applied research is such that its success depends upon the size of the reservoir of fundamental knowledge upon which it must draw. The rate of progress in the applied marine sciences will be determined in the long run by the rate of progress in the basic marine sciences.

The Committee has concluded that both the quantity and quality of basic research in the marine sciences can and should be increased substantially during the years ahead. Specifically the Committee recommends:

1. *The U.S. Government should expand its support of the marine sciences at a rate which will result in at least a doubling of basic research activity during the next 10 years.*[81]

It should be emphasized that doubling the basic research activity will require more than doubling the total expenditures.

A large part of the deliberations of the Committee were devoted to discussions of the conditions under which basic research can flourish. First and foremost, progress depends upon the interests, experience and creative imaginations of individual scientists. But the individual scientist does not work in a vacuum. He must have instruments and facilities. He must live in an atmosphere which is conducive to creative activity. These necessities in turn give rise to problems involving marine research laboratories—problems of leadership, financial stability, flexibility, growth, academic associations and physical facilities.

Not only for research but in order to exploit and use the oceans we need more detailed knowledge which can be obtained only through systematic surveys in three dimensions. These surveys should include such features as depth, salinity, temperature, current velocity, wave motion, magnetism and biological activity. It is essential that these surveys be conducted on an ocean-wide ocean-deep basis as quickly as possible. Our knowledge is now limited largely to waters 100 miles from shore and even here it is inadequate for present and future needs. Accordingly, the Committee recommends:

2. *The increase in support of basic research should be accompanied during the next 10 years by a new program of ocean-wide surveys. This will require a two-fold expansion of the present surveying effort.*

We believe that, on a long-range basis, basic research coupled with systematic ocean surveys are of paramount importance in solving a number of urgent practical problems involving military defense, the development of ocean resources and possible future increases of radioactive contamination of the seas resulting from the rapid development of atomic energy. However, research and surveys must go hand in hand with a vigorous and imaginative applied research and development program. Accordingly, the Committee recommends:

3. *The United States should expand considerably its support of the applied marine sciences, particularly in the areas of military defense, marine resources and marine radioactivity.*

The implementation of these general recommendations requires action upon a number of broad fronts. More marine scientists must be educated. Additional ships and shore facilities must be built. New instruments and techniques must be strengthened.

To achieve these aims in the next 10 years will necessitate many agencies of the

[81] In 1958 about $23 million were spent for applied and basic oceanographic research. The basic research share of the total was not over $9 million. About $8 million of this, including the 1958 share of IGY expenditures, were Federal funds.

(Editors note: Subsequent studies for this present report indicate that the level of support in fiscal year 1958 was about $30 million; details of these modifications to figures are discussed in Section VI.)

Federal Government working together both in planning and in providing the moneys.[82]

Taking into account the relative degrees of interest and importance of oceanography to individual agencies, the Committee recommends:

> 4. *The Navy and the National Science Foundation should each finance about 50 percent of the new basic research activity except ship construction. The Navy should finance 50 percent of the new research ship construction with the Maritime Administration and the National Science Foundation sharing the remainder. The Navy, through the Hydrographic Office, should finance 50 percent of the deep ocean surveys, while the Coast and Geodetic Survey should finance the balance. The Navy should sponsor complctely all military research and development operations. The Bureau of Commercial Fisheries should finance the greater part of the recommended ocean resources program. The Atomic Energy Commission should finance the major part of the research dealing withe problems of radioactive contamination of the oceans. The National Science Foundation and the Office of Education should sponsor jointly the proposed program for increasing scientific and technical manpower in the marine sciences. Efforts aimed at fostering international cooperation in the marine sciences should be sponsored by the Department of State, the international cooperation in the marine sciences should be sponsored by the Department of State, the International Cooperation Administration and the National Science Foundation. Other agencies should take responsibility for certain aspects of the proposed program particularly the Public Health Service, the Geological Survey and the Bureau of Mines.*

Although the bulk of oceanographic research and survey work must of necessity by financed by the Federal Government, the value of state and private funds cannot be overestimated. Such funds are especiallly helpful for supporting initial exploratory basic research and for staring new laboratories. Accordingly, the Committee recommends:

> 5. *Private foundations and universities, industry and State governments should all take an active part in the recommended program of expansion.*[83]

Recapitulating: the NASCO recommendations urged an immediate expansion in the national oceanographic effort, both for basic research and for oceanwide surveys, at least by a factor of two. The necessary funding was visualized as coming almost exclusively from the Federal Government, with especially rapid growth in sponsorship by the National Science Foundation.

In addition to the preceding general recommendations, the NASCO study set forth explicit details of a 10-year program.

Specific projects were outlined in the areas of basic research, of new resources and of radioactivity in the sea, and far more extensive hydrographic surveying. The number of new ships required both to replace existing, obsolete vessels and to enlarge the present fleet was also specified, together with needs for special vehicles for the exploration of the ocean and for new shore facilities. With such planning data, the capital and operating costs of this program were estimated in terms of a yearly budget, further broken down according to proposed sponsoring Federal agency.

The NASCO studies include comprehensive fiscal requirements for the next 10 years of oceanography. These data, however, have not been reproduced verbatim for a number of reasons. In the first instance, the proposed programs were expressed only in terms of *increase over Fiscal 1958,* used as a base, and were thus not available in the NASCO reports in terms of the *total required for each year or from each agency.* Secondly, the 1958 base itself utilized in the NASCO reports, though complete in most details, includes neither

[82] One method suggested for developing more effective interagency cooperation is through the proposed Federal Council for Science and Technology. This Council is described in "Strengthening American Science," a recent report of the President's Science Advisory Committee.

[83] NASCO Report, ch. 1, op. cit., pp. 6–8.

costs for hydrographic surveying by the Coast and Geodetic Survey nor the cost for rehabilitation of ships for oceanographic research by the Navy.

Finally, the NASCO report, while specifying the future (1960–69) costs of ship operation for studies of radioactivity in the ocean which would be conducted for the Atomic Energy Commission through the device of fund transfer, did not add this item to the total cost.

It should also be noted that all the proposals for the next 10 years in oceanography reflect expansion exclusively in terms of Federal sponsorship. Neither the program nor the fund requirements carry any detail on the extent to which additional support would be expected or provided from State governments or from increased endowments and grants from private or commercial sources. The NASCO report recommends stimulation of these sources in qualitative terms; but in lieu of any more specific detail, no further amplification of this point can be made.

Apart from modifications to the NASCO figures just mentioned, data have been tabulated in this report in a somewhat different form so as to distinguish more clearly the different segments of fiscal requirements, and so as to combine all of the research and surveying activities, and all of the laboratory and ship construction activities. The data have been presented in several alternate forms as well, to facilitate the interpretation which follows. All of these modifications to the NASCO data and reclassification of fiscal requirements have had the benefit of review by the Executive Secretary of the Committee on Oceanography. The revisions are still regarded as consistent with the initial proposals by NASCO and are, therefore, so identified.

Table 16 contains a breakdown of future oceanographic research budgets (proposed for Federal sponsorship) according to specific activity. From these data, it is possible to identify the different sectors of costs for:

(*a*) Basic research investigations.
(*b*) New resources.
(*c*) Radioactivity in the oceans.
(*d*) Hydrographic surveys and ship operation.
(*e*) Education and training.

Column 7 gives the total by year for all of these oceanographic activities, from which has been excluded new laboratories and research ships. Such capital expenditures are listed later in Table 16 including, in column 12, totals for capital equipment.

From this table it is clear that the program proposed by NASCO visualizes, for the next 10 years, a total expenditure of $867.21 million, of which $520.71 million is for direct research and survey activity and $346.50 million for capital equipment.

By a comparison in the table with actual expenditures for Fiscal 1958, the rate of increase proposed by NASCO can be determined. In the aggregate, research and surveying for Fiscal 1969 would be operating at an annual level of $68 million in contrast with 1958 operations of roughly $20 million, or an increase by a factor of 3.4.

As in the case of previously cited data concerning the existing level of activity, the original *NASCO data specifically excludes costs for military oceanography and for the operation of ships scheduled for programs in military oceanography or military surveying.*

TABLE 16.—*Breakdown of Federal oceanographic research budgets proposed for the next 10 years by NASCO, by activity*

[In millions of dollars]

Fiscal year	Research activities			Hydrographic surveys	Ship operations [1]	Education and training	Total, research surveys education and ship operation	New laboratories and research ships				Total capital equipment [1 2]
	Basic research investigations	New resources, biological and mineral	Radioactivity in oceans					Shore facilities	Survey and data center facilities	Special devices and vehicles [2]	Research or survey ships [2]	
1958 (actual)	[3] 6.16	[3] 4.00	[3] 0.45	[4] 2.75	[4] 7.05	0	20.41	0	0	[5] 0.19	[5] 3.50	3.69
1960 (proposed)	6.16	8.13	3.53	2.75	[6] 8.10	.80	29.47	2.39	0.76	7.40	39.80	50.35
1961 (proposed)	7.36	8.41	3.40	3.51	[6] 9.65	.80	33.13	3.80	0.76	9.50	38.90	52.96
1962 (proposed)	8.56	9.23	4.80	4.25	[6] 11.75	.80	39.39	1.70	1.50	9.60	42.25	55.05
1963 (proposed)	9.76	9.52	3.40	5.75	[6] 12.75	.80	41.98	6.00	1.50	10.90	31.30	49.70
1964 (proposed)	12.16	10.25	3.40	7.25	[6] 14.20	.80	48.06	5.80	1.50	10.50	27.55	45.35
1965 (proposed)	15.76	14.04	3.40	8.75	[6] 15.75	.80	58.50	3.54	1.50	10.50	21.35	36.89
1966 (proposed)	18.16	14.43	4.80	10.25	[6] 17.85	.80	66.29	2.00	0.76	10.50	11.40	24.66
1967 (proposed)	19.36	14.75	3.40	11.01	[6] 18.55	.80	67.87	0	0	10.50	0	10.50
1968 (proposed)	19.36	14.88	3.40	11.01	[6] 18.55	.80	68.00	.04	0	10.50	0	10.54
1969 (proposed)	19.36	14.90	3.40	11.01	[6] 18.55	.80	68.02	0	0	10.50	0	10.50
Total (1960–69)	136.00	118.54	36.93	75.54	145.70	8.00	520.71	25.27	8.28	100.40	212.55	346.50
Factor of increase, 1958–69							3.4					

[1] Does not include costs of operation of ships now employed or initially scheduled for military oceanography or military hydrographic surveys.

[2] Represents costs of all new ships, including those initially scheduled for military oceanography or military hydrographic surveying.

[3] Extracted from NASCO report, confirmed by ONR.

[4] Includes direct costs and ship operating costs of Coast and Geodetic Survey, not shown in NASCO report.

[5] Includes ONR reported costs to purchase bathyseaph *Trieste* and to rehabilitate research ships *Chain*, *Snatch*, and *Gibbs*.

[6] Includes ship operating costs for AEC activities through transfer of AEC funds, (omitted from table of NASCO report).

Source: NASCO Report, Ch. 1, Tables 8, 9, 13, and 16, as revised.

The same data have been broken down according to sponsoring agency in Table 17. The totals in Table 17 have been further separated into categories of operating costs and capital expenditures in Tables 18 and 19.

In the first instance, it is clear that the rate of funding is proposed to be increased in steps from $24 million in 1958 to $80 million in 1960, rising then to a level on the order of $95 million from 1962 to 1966, then dropping in 1969 to $78 million, and presumably in 1970, at which time new facilities would have been completed, to almost level funding of roughly $68 million. The reason for the immediate jump is clear from Table 19. In 1958, only $3.69 million were spent for provision of new ships and facilities; whereas in 1960 it is proposed that $47 million be allocated. This reflects, of course, the position taken by the NASCO Committee that any expansion in effort, any improvement in effectiveness, critically depends on the prompt provision of additional and up-to-date vessels.

Funds for conduct of research are also proposed, but with a more gradual increase reflecting slower expansion in manpower. The total for 1958 of $20.41 million was proposed to be increased for 1960 to the level of $32.62 million. From an examination of the breakdown in Table 18, it is clear that between Navy and non-Navy expenditures, by far the greatest increase lies in the civilian field—from $10.39 million to $21.47 million. The same trend has been proposed for the next decade.

TABLE 17.—*Federal appropriations for oceanographic research as proposed for the next 10 years by NASCO, by sponsoring agency* [1]

[In millions of dollars]

Fiscal year	Navy	C&GS	B of CF	MA	NSF	O of E	AEC	B of M	Total
1958 (actual)	[2] 13.71	[3] 2.99	[4] 5.29	[4] 0	[4] 1.44	[4] 0	[4] 0.67	[4] 0	24.10
1960 [5]	38.80	8.82	13.26	5.45	7.84	.50	[6] 4.80	.35	79.82
1961	38.85	9.08	19.15	3.80	9.79	.50	4.67	.25	86.09
1962	40.42	12.74	18.72	1.65	14.09	.50	6.67	.25	94.44
1963	43.82	11.69	17.71	0	13.04	.50	4.67	.25	91.68
1964	45.24	12.29	17.04	0	13.42	.50	4.67	.25	93.41
1965	42.70	12.19	20.32	0	14.76	.50	4.67	.25	95.39
1966	37.47	12.87	17.67	0	15.52	.50	6.67	.25	91.25
1967	30.38	9.42	17.49	0	15.66	.50	4.67	.25	78.37
1968	30.38	9.42	17.66	0	15.66	.50	4.67	.25	78.54
1969	30.38	9.42	17.64	0	15.66	.50	4.67	.25	78.52
Total (1960-69)	378.44	107.94	176.06	10.90	135.44	5.00	50.83	2.60	867.21

[1] Includes funds for new ships but not for direct research or operating costs for military oceanography.
[2] Actual expenditures, reported in NASCO survey, to which has been added $3,690,000 for rehabilitation of research ships *Chain*, *Snatch*, *Gibbs* and bathyscaph *Trieste*, as reported by ONR.
[3] Actual expenditures, reported informally by C & GS.
[4] Actual expenditures, reported in NASCO survey.
[5] Future budgets based on NASCO proposals for increases over fiscal 1958.
[6] Approximately $1,100,000 per year, cited by NASCO as transferrable from AEC to other agencies to cover ship operating costs are included in this table, although omitted in NASCO report.

Source: NASCO Report, ch. 1, Tables 13 and 18.

TABLE 18.—*Future research and operating costs proposed for Federal sponsorship by NASCO, by agency* [1]

[In millions of dollars]

Fiscal year	Navy	C&GS	B of CF	MA	NSF	O of E	AEC	B of M	Total non-Navy
1958 (actual)	10.02	2.99	5.29	0	1.44	0	0.67	0	10.39
1960	11.15	3.37	9.96	0	2.49	.50	4.80	.35	21.47
1961	12.75	4.08	12.05	0	3.39	.50	4.67	.25	24.94
1962	14.72	5.14	11.62	0	4.29	.50	6.67	.25	27.87
1963	17.47	6.24	14.41	0	5.94	.50	4.67	.25	32.01
1964	20.74	7.29	13.74	0	8.17	.50	4.67	.25	34.62
1965	23.20	8.39	17.02	0	9.51	.50	4.67	.25	40.34
1966	24.62	9.07	17.67	0	10.27	.50	6.67	.25	44.43
1967	25.13	9.42	17.49	0	10.41	.50	4.67	.25	42.74
1968	25.13	9.42	17.66	0	10.41	.50	4.67	.25	42.91
1969	25.13	9.42	17.64	0	10.41	.50	4.67	.25	42.89
Total (1960–69)	200.04	71.84	149.26	0	75.29	5.00	50.83	2.60	354.22

[1] Including direct research and ship operating costs, new laboratory facilities.

Source: NASCO Report, ch. 1, tables 1, 5, 11.

TABLE 19.—*Future capital requirements for new ships and vehicles, as proposed for Federal sponsorship by NASCO, by agency* [1]

[In millions of dollars]

Fiscal year	Navy	C&GS	B of CF	MA	NSF	O of E	AEC	B of M	Total
1958 (actual)	[2] 3.69	0	0	0	0	0	0	0	3.69
1960	27.65	5.45	3.30	5.45	5.35	0	0	0	47.20
1961	26.10	5.00	7.10	3.80	6.40	0	0	0	48.40
1962	25.70	7.60	7.10	1.65	9.80	0	0	0	51.85
1963	26.35	5.45	3.30	0	7.10	0	0	0	42.20
1964	24.50	5.00	3.30	0	5.25	0	0	0	38.05
1965	19.50	3.80	3.30	0	5.25	0	0	0	31.85
1966	12.85	3.80	0	0	5.25	0	0	0	21.90
1967	5.25	0	0	0	5.25	0	0	0	10.50
1968	5.25	0	0	0	5.25	0	0	0	10.50
1969	5.25	0	0	0	5.25	0	0	0	10.50
Total (1960–69)	178.40	36.10	27.40	10.90	60.15	0	0	0	312.95

[1] Costs of new laboratory facilities, while a capital expenditure, could not be separated from operating costs, by sponsoring agency; they are thus included in table 18.

[2] Costs of rehabilitation of research ships *Chain*, *Snatch*, and *Gibbs*, and bathyscaph *Trieste* had not been included in NASCO report. Thus, all capital requirements proposed by NASCO for the next 10 years are based on a zero expenditure for ships in fiscal 1958.

Source: NASCO Report, ch. 1, tables 5 and 11.

In this regard incidentally, it is of particular importance to note by comparing 1958 and 1969 figures in Table 18 that, whereas in fiscal 1958 direct costs of research were about equally split between military and nonmilitary activities, the NASCO proposal expects that by 1970 naval expenditures will have increased by a factor of about 2.5, whereas nonmilitary expenditures will have increased by a factor of 4. The civilian segment of a national program is thus visualized as being larger than the military, somewhat in contrast to the present implications for funding. At the same time, it should be recalled that this program of research does not include "military oceanography," according to definitions of Section V. Programs in military oceanography, which are estimated for fiscal 1961 to be at a level of $24 million, may reflect short-term rather than long-term military requirements and may thus undergo expansions and contractions depending upon the immediate needs. These activities, al-

though neither divorced from the naval (nonmilitary) aspects of oceanography nor non-Navy (civilian) aspects, nevertheless have been previously excluded by the NASCO Committee and, as will be indicated, were also excluded by the Navy itself when preparing the TENOC report. For consistency, they have been excluded from this analysis.

NASCO recommendations for new oceanographic ships, according to function, are listed in Table 20 and according to size in Table 21. The source of funding for these new vessels is given in Table 22; the corresponding funds, broken down by agency, were given in Table 19.

TABLE 20.—*NASCO recommendations for new oceanographic ships according to function*

	Research	Survey	Resources and fisheries	Total	Military R. & D.	Total with military R. & D.
Present fleet	11	18	7	36	9	45
Expected to remain operational in 1970	6	9	0	15	0	15
Present fleet to be replaced by 1970	5	9	7	21	9	30
Additional construction	11	11	7	29	11	40
Total new construction (replacements and additions)	16	20	14	50	20	70
Total fleet available in 1970	22	29	14	65	20	85

Source: NASCO Report, ch. 1, table 1.

TABLE 21.—*NASCO recommendations for new oceanographic ships according to size and cost*

Fiscal year put in service	Numbers of new ships [1]				Total displacement of new ships (tons)		Appropriations required (millions) [2]
	500 tons	1,200 to 1,500 tons	2,000 tons	Total	Yearly	Cumulative	
1959	0	0	0	0	0	0	$11.4
1960	2	2	0	4	4,000	4,000	28.4
1961	6	5	0	11	10,500	14,500	38.9
1962	6	5	2	13	14,500	29,000	42.25
1963	5	5	3	13	16,000	45,000	31.30
1964	6	3	2	11	11,500	56,500	27.55
1965	3	2	3	8	10,500	67,000	21.35
1966	3	3	1	7	8,000	75,000	11.40
1967	0	3	0	3	4,500	79,500	0
1968				0			
1969				0			
1970				0			
Total				70		79,500	212.55

[1] Note that new ships for military oceanography are included in this schedule even though other fiscal and program requirements in terms of personnel and related funding are not included in other schedules.
[2] Budget allocations are assigned to year preceding introduction of ship into service to reflect leadtime for construction.

Source: NASCO Report, ch. 1, table 4, as modified.

TABLE 22.—*NASCO recommendations for new oceanographic ships according to sponsoring agency, function, and size*

Agency	Size			
	500 tons	1,200 to 1,500 tons	larger than 2,000 tons	Total
Navy:				
Research		7	1	8
Military R. & D.	10	6	4	20
Survey	2	5	3	10
Coast and Geodetic Survey: Survey	2	6	2	10
Bureau of Commercial Fisheries: Fisheries	12	2		14
National Science Foundation: Research	3		1	4
Maritime Administration: Research	2	2		4
Total	31	28	11	70

Source: NASCO Report, ch. 1. tables 2 and 3.

Such detailed projections are inclined to be hazardous. For one thing, any single element of such a program may be difficult to justify in its comparison with other elements; the amounts proposed for new vehicles may be out of proportion to those for ships; that for disposal of radioactive waste out of proportion to that for basic research. The Committee, in making available the fruits of its study, intended only that it be considered representative of their general viewpoint and, in terms of size and scope, not to be interpreted too literally. For one thing, it was recognized soon after the data were published that they were available much too late for changes in program or funding to be reflected in fiscal 1960, which was the first of the 10 years suggested for operation of the plan. In addition, exact estimates for capital equipment are open to question; the NASCO figures were based on 1958 dollars and it is certain some inflation has already developed since that time which would make costs for new ships somewhat greater than had been used in their estimates. Nevertheless, the NASCO proposal is sufficiently explicit in terms of program content, rate of expansion in activity, approximate funding required, and sources of funding that their results have been used as a basis for study and planning both by the oceanographers themselves and by the Government agencies that originally requested the report.

The response to the NASCO report has been almost overwhelmingly favorable. Those Government agencies requesting the study have since evaluated the contents and recommendations and although no official comment has been released, there appears to be widespread satisfaction with the thoroughness, objectivity, and validity of the findings. Rear Admiral Rawson Bennett, Chief of Naval Research, acting in accordance with the request from the then newly formed Interagency Committee on Oceanography, asked the Coordinating Committee serving in a staff capacity to prepare a formal evaluation. Particular questions asked were:

1. Are the requirements realistic in terms of the value of oceanographic research to the Government?

2. Does the report recognize adequately the Government's existing oceanographic program?

3. How can the recommendations be coordinated with existing programs?

4. How can liaison and coordination between agencies be established and maintained?

5. What adjustments to present programs will be necessary to synchronize and coordinate with future expansion?

Informally, the CCO went on record stating that the NASCO recommendations were realistic, that the administrative problems raised by an increase in effort are no more difficult than the problems that the CCO encountered when it was originally formed. They further resolved that the CCO could provide the means by which future coordination, planning, and evaluation could be accomplished. In concurring with the NASCO recommendations, the CCO noted that, in general, they were relatively modest and that the specific numbers of ships, organizational responsibilities, etc., should be interpreted only as guidelines to the magnitude of effort.

The CCO specifically reiterated the inadequacy of the present supply of marine scientists and heartily concurred on the NASCO comments that converted ships were so uneconomical and inefficient that they should be promptly replaced.

Response in the scientific community has been almost universally favorable. While representing the work of only a segment of those engaged in oceanography, Dr. Harrison Brown, Chairman of the NAS Committee, has suggested that it probably represents the viewpoint of the entire profession:

> Mr. ANFUSO. Would you say Dr. Brown that your report represents the viewpoint of most U.S. Scientists concerned with oceanography?
>
> Dr. BROWN. Well, we haven't exactly taken a public opinion poll, but on the basis of replies that we have obtained when we solicited opinions, I would say that generally the bulk of the marine scientists in the country would agree with the broad objectives of the report and with the recommendations that we made.[84]

An unusual amount of publicity attended release of the NASCO recommendations. An aggressive stand by any group of scientists in support of their field is almost without precedent, and almost inevitably, feelings of anxiety develop among those in other fields who are concerned that their branch of science may suffer, if another is given unusual attention. By and large, this phenomenon results from the stiff competition for relatively limited amounts of funds for research. In this case, the NASCO report was prepared by individuals directly or indirectly participating in oceanographic research and, thus, the professional beneficiaries of any expansion in program. However, the stature of the members of the committee and concern for national problems suggests that the committee was not narrowly motivated. Moreover, and this point is developed subsequently, the recommendations by the NASCO Committee appear to have a conservative hue.

Ultimately, the amount of publicity that any announcements of this type receives depends to a very great extent upon the estimate by reporters of the newsworthiness of the material. The fact that so many newspapers, weeklies and journals of public affairs carried news items, comments, and analyses of the NASCO reports may well be interpreted to reflect the interest on the part of the general public on a then little-known field, a sincere interpretation on the part of the editors of the importance of the material and, not to be discounted, the clarity of the reports themselves.

[84] "Frontiers in Oceanic Research," op. cit., p. 11.

Congressional reaction, certainly stimulated by the publicity on the NASCO reports, is reflected in Senate Resolution 136. This step has been followed by a number of proposals for new legislation that are listed subsequently. The merit of this legislation is a matter that the Congress is now deliberating, but the fact that the level of congressional interest is so high is itself significant. In our form of democratic government, new legislation almost always bears a relationship to public acceptance which itself presupposes adequate public information.

Moreover, it is clear that, although those who reside on or near our coast are more enthusiastic about projects involving the sea, the published discussions may find equal interest by readers living inland. Missiles of intermediate range, launched from hostile submarines operating undetected in international waters off our shores, could reach 95 percent of the industrial complex of this country. Possible future control of climate by a better understanding of the processes of heat transfer to and from the ocean may well water the now arid States.

Oceanography is but one of a number of fields of science that have been cited as undernourished. At recent hearings by several Committees of the Congress concerned with oceanography, concern has been expressed over the hazards of emphasizing one area at the expense of others. Probably during the next few critical years a national policy will emerge, which among other planks, will assure that all deserving scientific efforts will be sponsored up to the limits of availability of manpower. Limits in manpower will put a very real ceiling on this activity. Recent figures on manpower recently released by the National Science Foundation are rather convincing in showing that the U.S.S.R. is serious in its intent to develop world leadership in the sciences. In a free society, motivating students to enter scientific fields may be the most critical problem, and certainly the NASCO reports underscore need for additional oceanographers. Students are attracted to science because of a specific appeal rather than a general one, and the recent publicity of opportunities to press into the unknown of the sea may well provide incentives. Some of those who enter biology because of initial interest in marine science may eventually end up in medicine.

B. PROPOSALS BY THE U.S. NAVY FOR THE "NEXT TEN YEARS IN OCEANOGRAPHY" (PROJECT TENOC)

The Navy's traditional responsibilities over the sea domain and its need for knowledge of the ocean, the bottom, and of the interface have been discussed earlier. Yet, despite its activities in charting the sea which date from 1842, until very recently the Navy apparently had no coordinated program of research focused on the oceans. The U.S. Hydrographic Office in 1946, and the Office of Naval Research in 1947 undertook specific programs aimed at increasing the basic understanding of the sea, but during intervals when budgets were rising and falling, and the importance of research was considered a "sometime thing," there is little evidence either of a climate for a coordinated naval program in oceanography or the fact of its development.

It was thus in 1957 that the Office of Naval Research, in concert with other government agencies, turned to the National Academy of

Sciences for studies of the national posture. Concurrently, the Navy undertook a more modest evaluation of its own activities and of its long-range interests in the oceans. Beginning in 1957, and concluding in October 1958, the Office of Naval Research developed what has been termed the TENOC program.

The significance that the Navy attaches to this program is attested by its endorsement on January 1, 1959, by Adm. Arleigh A. Burke, Chief of Naval Operations, explicitly stating that it will be supported "within budget limits in the Navy's research and development, shipbuilding, and military construction programs."

The TENOC report concerns itself primarily with present and planned programs of the following civilian laboratories which are heavily sponsored by naval contracts; it does not include the inhouse research of the Government laboratories although supplementary studies are now in progress to develop such information. Also, military oceanography and hydrographic surveying were omitted.

TABLE 23.—*Oceanographic laboratories studied in TENOC*

Name	*Percentage of effort sponsored by U.S. Navy, Fiscal Year 1959*
Scripps Institution of Oceanography	50
Woods Hole Oceanographic Institution	70
Lamont Geological Observatory	33
Hudson Laboratory	100
University of Miami	40
University of Washington	65
Texas A&M College	20
Chesapeake Bay Institute	33
Narragansett Marine Laboratory	45
Oregon State College	90
New York University	50

Source: TENOC report.

For each of these laboratories, the current program was inventoried in considerable detail, as were the personnel and available facilities including ships, buildings, and laboratories. The annual budgets for Fiscal 1958 and Fiscal 1959 were then listed, including that percent of the 1959 budget supported by some element of the Navy. (See Table 23.)

For each of these laboratories, specific recommendations were then developed for scientific programs to be conducted for the Navy during the next 10 years, including program content, and details of the rate at which personnel, facilities, ships and aircraft should be increased. Finally, for each of these laboratories, a budget was projected for this 10-year interval.

The total program entails an annual increase of R. & D. funding of approximately $2 million, from a fiscal 1959 base of $7,600,000. Increasing by approximately $2 million each year from 1959 to 1969, the funding for Fiscal 1969 would be $27,814,000. Additionally, the TENOC program recommended a total 10-year expenditure of $11,814,000 for buildings, $51,600,000 for 18 oceanographic research ships and $1,000,000 for pier construction.

It is difficult to draw exact comparisons between the TENOC and NASCO recommendations because the scope of the two studies was different. The NASCO report was concerned with the entire national

program including basic research, but also including attention to the development of new marine resources, to problems in radioactive waste disposal, and hydrographic surveying. The TENOC report, on the other hand, is concerned only with basic and applied contract research in which the Navy has specific interest. It is possible, however, to compare the TENOC recommendations with the particular segment of the NASCO report allocated by the Committee on Oceanography as a Navy responsibility and this comparison is given in Table 24.

TABLE 24.—*Comparison of Navy operating budgets proposed by NASCO and TENOC* [1]

[In millions of dollars]

Fiscal year	NASCO [2]	TENOC	Fiscal year	NASCO [2]	TENOC
1960	11.15	9.91	1965	23.20	20.84
1961	12.75	11.71	1966	24.62	22.78
1962	14.72	14.71	1967	25.13	24.62
1963	17.47	15.76	1968	25.13	26.21
1964	20.74	18.99	1969	25.13	27.81

[1] New obligational authority, not including amounts for new ships.
[2] Includes some amounts for inhouse basic (nonmilitary) oceanography not included in TENOC.

Source: NASCO, ch. 1, and TENOC (ONR) Report.

In general, the two programs are consistent in terms of identifying the increasing needs for a study of the oceans, of the problems currently entailed in meeting that need and of the expanded program that these studies recommend.

C. PROPOSALS OF THE INTERAGENCY COMMITTEE ON OCEANOGRAPHY (ICO)

The question of how much is enough must always be answered in arbitrary terms. Thus, there are no positive criteria with which these two proposals can be confronted. Moreover, there is no single Federal agency charged with the responsibility of determining how much is enough, insofar as national efforts in oceanography are concerned. The Interagency Committee on Oceanography (ICO) has been charged by the President, however, with the responsibility in this area, and this particular group, it will be recalled, operating within the framework of FCST, has taken into consideration both the NASCO and TENOC proposals and generated a Government-wide program. This program has been expressed primarily in terms of funds rather than subject matter content and the projection for the immediate future and for the next 10 years was recently described to the Congress by James H. Wakelin, Jr., Asst. Secty. of the Navy for Research and Development, and present chairman of the ICO.[85]

> Recognizing the seriousness of inadequate oceanographic information from the scientific, technical, and military points of view, the Federal Council for Science and Technology established a subcommittee last summer to prepare a coordinated national oceanographic program. This committee, now called the Interagency Committee on Oceanography, has recently been made a permanent instrument of the Federal Council with representation from the Departments of Defense, Commerce, Interior, Health, Education, and Welfare, the National Science Foundation, and the Atomic Energy Commission.
>
> The Interagency Committee carefully reviewed the report of the National Academy of Sciences-National Research Council's Committee on Oceanography.

[85] "Frontiers in Oceanic Research," op. cit., p. 43-48.

In this report the Academy recommended a minimal program for long-term growth at an achievable rate in training of scientific manpower, construction of adequate ships and laboratories, as well as a technical program for research and ocean surveys.

The Interagency Committee concurred generally with the National Academy and concluded that the report accurately stated the Nation's scientific needs in oceanography. [Emphasis supplied.] In the development of a national oceanographic program, we are concerned on the one hand with the assessment of the needs of oceanography and, on the other, with the limitations upon its development. The critical limitations are scientific manpower, funds, and time. Of course, I refer to a special kind of time—leadtime for the construction of ships and shore laboratories and for the training of the additional scientists.

The Interagency Committee recommended to the Federal Council that the United States undertake a substantial and orderly expansion of activity in oceanography. The Committee stated that vigorous action must be taken to stimulate the growth of educational programs, that a permanent interagency committee should be established to review and coordinate the national effort and that international cooperation is essential to the research and survey program.

These recommendations were accepted and endorsed by the Federal Council.

The Interagency Committee then developed by joint planning the budget for a 10-year national program to implement these general recommendations. In the development of the initial funding request for this program in the fiscal year 1961 budget, the agencies had to consider other competing needs of their respective departments while striving to give greater support to oceanography.

The total funding requested for the oceanographic program in fiscal year 1961 totals about $56 million, an increase of almost 50 percent over the fiscal year 1960 level of $37 million. For the previous year, fiscal year 1959, funds for this work amounted to $24 million.[86]

I feel that this program provides for growth at a reasonable rate and that it satisfies the most critical needs of the departments and agencies in the field of oceanography.

All of the Secretaries of the departments and heads of the agencies represented on the Interagency Committee have indicated to me that they consider this Committee an effective means for achieving coordination and cooperation in our national program. I believe that this organization, assisted by working groups or panels comprised of representatives from the interested Federal agencies will be responsive to the needs of this country.

* * * * * * *

What will a 10-year program require in terms of funds, facilities, and manpower? The National Academy of Sciences report indicated that the program would cost $651 million in 1958 dollars over and above the rate at which the program was then being supported. This estimate is probably low when translated into 1961 dollars because the cost of doing business has increased.

Also, we believe that the unit cost of construction of ships has been underestimated. Taking these factors into consideration, the Interagency Committee has estimated that the total cost will approximate $1 billion during the 10-year program if our goal to double our present capability is to be realized. This is a modest goal when the level of our present knowledge is considered in relation to our needs. And I would like to say that doubling the present activity in oceanography will require more than doubling the rate of expenditures because of the capital investments required.

The Interagency Committee has estimated the major cost elements of the 10-year program to be as follows:

(*a*) Oceanographic research and ship operations, $490 million.
(*b*) Ocean surveys and ship operations, $144 million.
(*c*) Construction of 78 new ships and facilities, $405 million.

In the first few years the annual cost of this program will of necessity be greater than the average cost per year over the 10-year period because of the immediate need for additional ships and shore facilities—both are high cost, long leadtime items. Little expansion can take place unless these capital items are provided.

The United States currently operates about 52 ships, mostly of small size, for oceanographic research and surveys. About 30 of these will require replacement during the next 10 years because they will be overage.

The recommended 10-year program requires the construction of 78 new ships of sizes varying from about 500 tons to about 4,000 tons. Conversion of existing

[86] See Table 25 for a comparison with initial estimates by ICO.

ships, principally from the Navy Reserve Fleet, has provided us with an oceanographic capability in the past and will undoubtedly continue to do so in the future for many purposes.

However, construction of new research ships in preference to the conversion of existing hulls is considered essential for a number of reasons. The Navy is making a study of the efficiency and economy of new construction versus conversion for various applications to point to the most feasible methods of providing the Navy with the required oceanographic ships in the next 10 years. This includes those ships we plan to make available to nonprofit universities and institutions as well as those for inhouse laboratories.

* * * * * * *

By 1970 I believe we can expect the annual cost of the program to level off at approximately $85 million. This annual investment will offer a great return in national defense and in economic benefits to this country and to mankind. Here I would like to emphasize that beginning in fiscal year 1962 the annual cost of the program for several years may require funding in excess of $100 million.

This large sum of money will be required specifically for the construction of ships and shore laboratories necessary for a significant expansion in the program. The training and educational program, however, will not be a large percentage of the total program cost. We feel that approximately $15 million will provide the means whereby an adequate number of oceanographers can be trained in the next 10 years. This figure is a cost of education only—not the cost for facilities at educational institutions.

The Navy, by far the largest supporter of oceanographic research, contracts with universities and nonprofit institutions for about three-fourths of its basic research program, the remainder is conducted in Navy-operated laboratories. The funding of this research and development work constitutes our contribution to the national oceanographic program. In addition, the Hydrographic Office of the Navy conducts our extensive military survey program and the technical bureaus of the Navy contract for many other closely related military programs scattered throughout universities, Government laboratories, and industry. The cost of this effort approximates $14 million for military surveys and about $10 million for military research. Because of the peculiarly military character of these programs, their funding is not included in the national oceanographic program.

* * * * * * *

The report of the National Academy of Sciences has focused national attention on the needs of oceanography. The Interagency Committee has demonstrated its effectiveness in a short time as a coordinating mechanism. In response to the tasks facing it, the Committee has established working panels for specific purposes. The function of one panel is to plan and coordinate our ocean survey program. A second panel has the responsibility for working out the details for establishing and the policies for operation of a national data center. We are considering additional panels for training and education, for basic research, and possibly one for special devices and instrumentation.

Our next major task is to develop the budget for fiscal year 1962. Each agency's program and the national program as a whole will be reviewed critically by the committee for balance and technical validity. The final result must be adequate to meet our most immediate needs using the resources available while emphasis must be placed on providing the tools we need on a long term basis.

We expect to seek endorsement of this program and budget from the Federal Council for Science and Technology and approval from the President before presenting it to Congress as a complete national program in oceanography. [Emphasis added.]

* * * * * * *

TABLE 25.—*Comparison of recommendations for Federal support of oceanography, fiscal year 1961*

[In millions of dollars]

Agency	NASCO [1] [2]	ICO [3]	Actual budget submission [3]
Navy [4]	38.85	40.511	22.919
Commerce	13.13	36.114	13.233
Interior	19.15	20.418	7.448
Health, Education, and Welfare	.500	1.795	.664
National Science Foundation	9.79	18.580	9.280
Atomic Energy Commission	4.670	2.810	2.210
Total	86.09	120.228	55.754

[1] Based on 1958 dollars.
[2] From Table 17.
[3] Source: Supplementary data provided by Assistant Secretary of the Navy James Wakelin to House Committee on Science and Astronautics, "Frontiers in Oceanic Research," op. cit. p. 53.
[4] Not including military oceanography.

TABLE 26.—*Comparison of NASCO and ICO budget proposals for Federal sponsorship during the next 10 years*

[In millions of dollars]

	NASCO [1] [2]	ICO [3]
Oceanographic research and ship operators	370.7	490
Ocean surveys and ship operators	150.0	144
Construction of new ships and facilities	346.5	405
Number of new ships	(70)	(78)
Total estimated cost	867.2	1,039
Annual cost after 1969	68.0	85

[1] Based on "1958" dollars.
[2] Source: NASCO Report, ch. 1, various tables as revised; see Table 16 in this report.
[3] Source: Testimony by Assistant Secretary Wakelin—"Frontiers in Oceanic Research," op. cit., pp. 43–53.

Comparisons between the NASCO proposals and those of the Interagency Committee on Oceanography are set forth in Tables 25 and 26. These show the relative budgets proposed for fiscal year 1961, and totals proposed for the ten-year interval 1960–69. However, no data were available from the ICO on how this ten-year budget was broken down on a year-by-year basis for comparison with similar data presented.

It is clear from the comparisons that the two are in agreement, both in principle and detail. Conceding the fact of inflation, the NASCO estimates based on 1958 dollars would certainly be revised upward to make them consistent with (presumably) ICO 1960 dollars. Moreover, the NASCO Committee everywhere contended that they had taken the most conservative viewpoint when formulating budgets.

It might thus be concluded that for present purposes of planning, the ICO overall numbers are the more realistic. Thus, all of the fiscal details compiled by NASCO and presented in earlier tables could be revised upward in almost exact proportion, roughly 15 percent.

D. IMPLEMENTATION OF THESE PROPOSALS

In light of these unusually detailed and long-range plans, and of their informal if not formal endorsement, the question arises as to the extent to which the proposed programs been have implemented. In the first instance, have the plans themselves been embodied in an official statement of national policy? Secondly, have the proposals, with or without any statements of policy, received the financial support that is the index of intent?

From Table 14, it is evident that soon after the NASCO studies began, some increase in funding developed, particularly in the Navy and National Science Foundation. A major question arises, however, as to the continuity and enhancement of this fiscal momentum.

It should be clear from the comparisons in Table 27 that the recommendations with regard to needs, either by NASCO or the ICO, have not been met, either for Fiscal 1960, or as proposed, for Fiscal 1961. This does not necessarily mean that the rate of research effort has been diminished or inhibited accordingly, because substantial proportions of these proposals represent appropriations for new construction. However, lack of growth in oceanic research of civilian agencies is also apparent.

The most unwholesome effect of this delay in increased funding is likely to be noticed in future years as the inadequacy of the existing research fleet becomes all the more pronounced, and the desired expansion of the field then retarded by lack of facilities.

TABLE 27.—*Comparison of proposed and actual budgets for Federal sponsorship of oceanography, fiscal years 1960–61*

[In millions of dollars]

Fiscal year	Proposed by NASCO	Proposed by ICO	Budget appropriated or submitted
1960	80		37
1961	86	120	56

Source: NASCO and ICO reports.

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IX. Commercial and Industrial Ventures in the Sea

Although oceanic research is currently attracting only the scantiest of non-Governmental support, industrial and commercial interests already maintain a heavy capital investment related to the sea, and private engineering ventures are now undergoing a resurgence of activity. The merchant marine and commercial fishing fleets represent the obvious elements of the maritime industry. Often overlooked in this context, however, is the installation of submarine cables attended by all of the charting, engineering research and development, and operations at sea which those bold ventures require.

Another relatively recent activity has been the exploration and drilling in off-shore waters. Although mainly confined to the relatively shallow depths near shore, problems of operating from a platform are far more expensive and demanding than when drilling from the stable, predictable surface of dry land. Losses of offshore rigs from the impact of wind and waves have underscored the engineering problems of pushing beyond the beach.

A new era of engineering activity in and under the sea developed by private funds appears in the offing but, as in the case of commercial fishing, cable laying, etc., these ventures are more to be regarded as engineering developments rather than as projects in either basic or applied research. Several examples are presented in what follows, primarily to identify further the contemporary potential of the sea as a factor in our economy and areas of fruitful application of research results.

The industrial outlook has been described by a number of individuals and organizations in optimistic tones and an example is cited in the following:

> As flights into space become routine in the next decade, the Nation may turn in another direction for the next great research frontier—and new multi-billion dollar marketing opportunities. Close at hand, but still largely out of reach, the depths of Earth's oceans are in many ways more a mystery than outer space. The coming drive to plumb the ocean's secrets will mean a great new source of profits for industry. As the navies of the world slowly submerge, demand for equipment that can function under water will burgeon. As the industrial nations exhaust many of the natural resources of the land surface, submarine miners will increasingly exploit the incredible mineral wealth of the oceans and as the world's population expands beyond the capacity of arable land to feed it, the sea will become a critically important source of edible flora and fauna. * * * Although the objective of the oceanographers is more scientific knowledge of the ocean and the ocean floor, commercial benefits are sure to follow. Here is one example: leading oceanographers are convinced that underwater telephone cable breaks are the result of ocean-bottom landslides. If and when oceanographers are able to predict where such displacements of bottom soil will take place, the telephone companies will be able to avoid multi-million dollar repair bills by laying cables elsewhere or by other methods. * * * When all the current activity connected with the oceans is evaluated, the dimensions of present and potential market opportunities look really impressive.[87]

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[87] "Exploiting the Oceans: Industry's Next Frontier," *Dun's Review*, February 1960, pp. 55–58.

A. RECENT PROJECTS

1. Undersea pipelines

Petroleum has become increasingly vital to the economy of the world during the past few years and expanded offshore drilling and production have brought about a great demand for submarine pipelines. In some instances, these are made up from individual sections of pipe and laid in a continuous line from a slowly moving barge. In other cases, they may be made up in long sections on shore and successively pulled into place. At the present time, perhaps the most daring project of all is now being projected for a crossing of the Mediterranean from North Africa to the coast of Eastern Spain for the undersea transportation of natural gas and even gasoline. Apparently the crossing will be made by a bundle of 12 pipes, possibly of plastic materials.

That project undoubtedly is the forerunner of a network of pipelines across narrow seas and straits all over the world. As one example, the Suez Canal will cease to be a critical bottleneck to the free world if this technique is developed.[88]

2. Undersea tunnels

Formal proposals for the construction of a tunnel under the English Channel date back some 85 years, at which time construction actually began. The engineering feasibility using more contemporary techniques has now been well established and, overcoming the traditional political objections of Great Britain, that country and France are now negotiating with private industrial concerns for construction of a tunnel from Dover to Calais, an underwater distance of about 20 miles. The terminals would be 44 miles apart and the tunnel 32 miles between portals. The projected tunnel would include an electric railway with flat cars to carry automobiles while passengers ride in separate accommodations. Trains would cross in about 35 minutes and on this basis, 1800 cars could be shuttled every hour. About 5 years will be required for construction involving roughly $250 million.

Generally, the pressure of increasing traffic and financial success of toll road operation should help revive the demand for underwater tunnels in places where bridges are not practical.[89]

3. Offshore mining.

Although mining of coal by conventional processes of extraction has been extended under the sea in many parts of the world, the mining of solid materials from the ocean floor is just beginning.

The Grand Isle Sulphur Mine in the Gulf of Mexico will soon operate from a very large and elaborately equipped steel tower structure. Among other noteworthy features, the plant will use hot sea water in the process of melting and handling sulphur. Also, the hot suplhur-bearing liquid is transported seven miles to shore through a heated pipeline.[90]

International agreement on ownership of sea-bed resources was tentatively settled by the 1958 Convention on the Continental Shelf, so that questions which have previously inhibited offshore exploration may now be answered.

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[88] "Frontiers in Oceanic Research," op. cit., p. 69.

[89] "Channel Tunnel Plans," Manchester Guardian, Apr. 28, 1960. See also "Frontiers in Oceanic Research." op. cit., p. 70.

[90] "Frontiers in Oceanic Research," op cit., p. 70. Operation subsequently reported as started on June 18, 1960.

4. Devices for operations under the sea.

A number of operations on the floor of the deep ocean appear best solved by the use of robot, remotely operated equipment. As an outgrowth of problems encountered in naval project termed "Artemis," a vehicle described as the Remote Underwater Manipulator (RUM) has been designed and recently put into successful operation. It resembles a tank and is powered and controlled remotely by means of lightweight coaxial cable. Mobility is achieved on tracked wheel assemblies to which is affixed a mechanical arm similar in most respects to the type of manipulator used for remotely handling radioactive substances. The RUM vehicle can carry a payload of 1,000 pounds without exceeding a bearing capacity of 1.20 pounds per square inch. It can maintain a speed of 2.6 knots and will travel to the limits of its five-mile-long cable. Its total weight is 24,220 pounds. Guidance and control are accomplished from a shore-based operating station, and through the use of underwater television and illumination the operator will be able to view operations of the vehicle so as to make effective use of the prosthetic arm.[91]

5. Project Mohole

Because what lies beneath the Earth's crust, 7 to 15 miles from the surface, is of such vital importance to the understanding of the origin and geophysical processes of the Earth, plans are now being made to drill directly through the crust into the mantle. This program, dubbed "Project Mohole," derives its name from the Mohorovicic discontinuity which represents the interface between the more familiar crust and the (as yet) unseen mantle.

Oil wells have been successfully drilled to approximately 26,000 feet, which is far short of the 100,000 feet at which the discontinuity is estimated to lie below the surface of continental masses. In the oceans, however, this discontinuity rises to within 15,000 feet of the ocean bed. It is thus proposed to undertake the drilling at sea so as to reduce by a significant amount the depth of hole required.

With amelioration of the drilling problem, the sea location generates another problem—that of operating in deep water. Offshore wells on the Continental Shelf are seldom in water over 170 feet. The known existence of oil in deeper water, perhaps 1,500 feet off the coast of California, has stimulated feasibility studies at sea by drilling from a floating barge. But Project Mohole visualizes drilling in 15,000 feet of water. Lessons from this experience have direct application to off-shore drilling and could very well lay the technological foundation for future operations in deeper water.

6. Salvage

Man has always sought treasure, and the lure of easy wealth from sunken ships has fascinated many an adventurer. Few, however, found the profits they expected, for the salvage in any but the shallowest of protected waters (where shipwreck is least likely to occur) has proved enormously difficult. At that, operations have almost always been limited by the depths to which human divers could descend to work—linked to the surface by an air-filled umbilical cord.

[91] Further details are developed in Artemis Report No. 6 of the Marine Physical Laboratory, Scripps Institution of Oceanography.

With the engineering developments of the future, salvage may be placed on a sound business basis, free of the technical limitations to shallow water, and of the high risk that attends these endeavors.

7. Submarine cables

After years of unbelievable frustration, disappointment and failure, the *Great Eastern* succeeded in laying the first transoceanic cable between Valentina, Ireland, and Newfoundland in 1866, and thus established the feasibility of this mode of telegraphic communication. Submarine cables were eventually developed to accommodate telephone as well as telegraph communications, and by 1929, there were some 360,000 miles of such cable in operation.

Activity in this field has been greatly stimulated by the technological development of "repeater stations" wherein electronic amplifiers having proved reliability and long life may be embedded at intervals within the cable itself, and thus afford high quality voice transmissions over unlimited distances. Added to this development is the use of coaxial cables and automatic switching systems which permit the use of one set of cables for a number of simultaneous transmissions, in fact as many as 120 on a single coaxial line.

As a consequence, a sharp increase has been noted in new submarine cables reported as planned for the near future. Included are:

(*a*) Puerto Rico to Antigua to Brazil (British Cable and Wireless).

(*b*) Hawaii to Guam to Wake to Philippines to Okinawa to Japan (Atlantic Telephone & Telegraph) (A.T. & T.).

(*c*) Transatlantic 60 channel (British Cable & Wireless).

(*d*) Transatlantic 120 channel (A.T. & T.).

(*e*) New Zealand to Hawaii to Vancouver (B.C. & W.).

Although cable laying is always preceded and accompanied by hydrographic surveying, the plotting of submarine cables may now be undertaken with a higher level of precision. Charts are anticipated whereby cable locations are shown with great accuracy so that fishing boats in the areas can take necessary steps to avoid accidental cutting of cables by trawling operations. Since such cables carry military as well as civilian traffic, the loss of such cables is regarded as extremely serious, particularly during intervals of intense sunspot activity when long-distance radio circuits are lost. Protection of such cables from intentional dismemberment constitutes another problem of underwater engineering stimulated by a tense international situation.

B. INCENTIVES FOR COMMERCIAL SPONSORSHIP OF RESEARCH

Most research and development programs appear to benefit from combinations of participants, both in terms of performance components and in terms of financial sponsorship. When research is heavily dominated by too few interests, certain ingredients of breadth, vigor, continuity, and imagination may be lost with resulting limits in achievement. In our system of government, a suitable mixture is not something that can be deliberately achieved. The freedom of choice must be preserved; the mixing then occurs entirely as a consequence of incentives.

Considering the lack of industrial participation in research (not engineering activities in the sea), either in terms of performance or sponsorship, the House Committee inquired of one of its witnesses at recent hearings as to the implications:

1. Q. What are the specific difficulties of engineering operations under the sea as compared with those on the surface of the sea and how do these problems compare with those of, for example, establishing a manned station in space?

A. Operations under the sea are governed primarily by the great pressures and by the vulnerability of humans and devices to those pressures. Supplying air to people under water would be relatively simple except that the human body is vulnerable to the "bends," to oxygen poisoning, and to narcosis when breathing air under pressure. Therefore, all human operations more than a few feet below the surface must be protected structurally so as to approximate sea level conditions for the operators.

These problems are similar to those of operating in outer space, where protected breathing is likewise the most important problem. In outer space, the operator is also endangered by wide temperature changes, high energy radiation, and small meteors—hazards which are not found in the sea.

2. Q. The program recommended by the Committee on Oceanography visualizes financial support primarily from Government sources. Do you believe that oceanographic research can attract private venture capital?

A. Oceanographic research will attract private venture capital in those areas where a near future profit can be predicted; for example, in offshore oil surveying and drilling.

Other areas, like conversion of salt water to fresh water, will require subsidy for a few years until the processes or projects gradually can be made economical, at which time further improvements may well be sponsored by industry.

In still other areas, like the effects of the oceans on weather, a commercial profit is difficult to foresee, and the entire programs will require Government support.

3. Q. What kind of incentives could be established, perhaps through congressional legislation, that would encourage investment of private capital?

A. Investment of private capital could be encouraged in several ways.

(*a*) A sufficiently stable legal and tax environment for reliable planning by industry.

(*b*) Special weather forecasting, rescue, and other protective measures where needed.

(*c*) *Favorable tax concessions or subsidies to encourage marginal industrial ventures. This requires, of course, provision for incentives to outgrow the need for such support.*[92] [Emphasis added.]

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[92] "Frontiers in Oceanic Research," op. cit. (testimony by Dr. James E. Lipp before the Committee on Science and Astronautics), pp. 75–76.

X. Analysis of Proposed Ten-Year Programs in Oceanography

Three separate appraisals, by the National Academy of Sciences Committee on Oceanography, by the Navy and by the Interagency Committee on Oceanography, have been made of the degree and urgency of needs by the United States for a national program in oceanography. All three recommended an immediate acceleration of program. All three studies also brought forth long-range proposals in varying detail outlining the rate at which the present level of effort could be accelerated.

While these 10-year programs were assembled from a detailed collection of project components, a comparison and analysis of program content on an item-by-item basis is less significant than the broader goals and means proposed for their accomplishment, particularly in the context of this report related to legislative interests of the Congress.

In summary, the rate of effort would be increased by a factor of between 3 and 4 during the next 10-year interval. At that time, the annual Federal appropriations would run around $85 million, in contrast to the Fiscal Year 1958 base of about $24 million. Such expansion is deemed possible, however, only if there is a collateral program of shipbuilding to provide an up-to-date fleet of research vessels and other special vehicles vitally necessary for increased observations at sea. During these 10 years, approximately $405 million would be required for capital expenditures, thus increasing the annual funding requirements during the buildup to over $110 million per year. Stimulation of interest on the part of students and qualified scientists alike to supplement the presently limited base of manpower was considered equally vital.

There follows some discussion of the implications of these proposals and of the problems and alternative solutions which have been identified in any program of expansion.

A. Problems in Program

First, how much should the national effort be enlarged? Those studying the need for oceanic research, both scientists and administrators, would ordinarily be reluctant to place "quantitative" indices on basic research, much less on rates of acceleration. Nevertheless, the comment is found frequently in the proposals that the activity should be at least doubled. This may have been another way of saying that the increase should be enough to make the necessary difference between the current rate and that compatible with the projected needs. *With such specific estimates, it is possible to program the growth on a far better planned and rational basis than would be possible otherwise, and to avoid the losses which inevitably attend a crash program.*

Those responsible for such planning, however, would be the first to agree that the goal of doubling research activity in 10 years is not a rigid standard that must be invoked regardless of other future

developments. Even the single objective of gaining a basic knowledge of the ocean more promptly than is possible without such growth carries with it the implication that any breakthroughs would be exploited to the fullest, either for reasons of technological gain, with the collateral economic or military benefits, or for reason of national prestige which, although a new factor in national planning, has been recognized as a necessary part of our philosophy of providing for the maximum security of the Nation.

Although all three proposals use the phraseology "at least doubling", the reader may recognize that details of the proposals entail something larger.

Consider the rate at which oceanography was growing when the NASCO reports were prepared as an indication of what might be projected to the future:

> Information was obtained from Hiatt's "Directory of Hydrobiological Laboratories" which was compiled during the fiscal year 1953. As an additional check, an abstract of the comparative information for 1953 and 1958 was sent to the directors of 28 laboratories for which data from both years were available. * * * The laboratories in question listed a total expenditure of about $8 million in 1953 and $14 million in 1958, an increase of 76%. * * * Nevertheless, the analysis suggests an inflationary factor of at least 30% and possibly more, and the real growth might therefore be of the order of 30–45% in five years. * * * The present rate of growth is more in keeping with the ability of science to produce new oceanographers and to supply the ship and shore facilities that they require. An increase of 30–45% in five years is equivalent to 70–110% in ten years. The recommendation for doubling of oceanographic research in the next ten years contained in the first chapter of this report therefore seems well within our capabilities and in line with a moderate acceleration of our present growth.[93]

Thus, doubling the rate of activity over the next 10 years on an *absolute* basis reflects little more than the present rate of growth for which no special measures to foster expansion would be necessary. In a sense, this viewpoint contradicts other aspects of the tone of urgency in the NASCO recommendations. (It is certainly agreed that during the last 5 years when the rate of effort increased, there were virtually no expenditures for capital equipment; so that pleas for increased funds could be justified on the grounds alone that the present fleet cannot accommodate the increased growth.)

Would the size of oceanographic effort in the United States double on a *relative* as well as an absolute basis? During the next 10 years, research and development as a broad field of activity is certain to expand. During the 3 fiscal years 1958, 1959, 1960, Federal obligations for research and development amounted to $5.9, $7.9, and $8.1 billion, respectively.[94] While trends are difficult to extract from such a limited number of statistics, it may be that the rapid rate of national growth has slowed following the typical "S-shaped" curve that so often describes some element of human endeavor. Nevertheless, the gross national product has been expanding at an annual rate of about 3½ percent, and the national research and development budgets, both Federal and industrial, have shown a pattern of growing faster. Following these projections, in 10 years one might suppose that, at the very least, the national research budgets would be 75 percent greater than at present. In terms of 1958 dollars, normal expansion by 1970 might well double. If that be the case, then doubling the oceano-

[93] NASCO Report, ch. 12, op. cit., p. 8.
[94] "Federal Funds for Science VIII", NSF 59-40, p. 3.

graphic research program would mean that *relatively*, it would not have grown at all.

Considering the unusual vigor with which these proposals for research have been pursued, it is natural to conclude that all three studies intended that the special acceleration of the program would result in gains over what would be realized if the field of oceanography were allowed to mature in its own good time, and by purely random processes of growth. Apparently expansion by something more than a factor of two was intended.

A close examination of the proposals reveals, that in terms of details, an expansion by a factor of 4 is actually involved, rather than by the factor 2.

For example, the proposals noted that the number of scientists that can be effectively associated with each oceanographic research ship (in terms of both those at sea collecting data, and those remaining at the laboratories planning expeditions or analyzing and interpreting earlier findings) amounts to roughly 60 per ship. If the fleet of research and survey vessels is expanded to 85, as the NASCO report visualizes, then the number of professional staff that would be correspondingly employed numbers about 5,100. The number listed as active in the field in 1958 was 1,548. As more laboratory facilities are added by which conditions in the ocean can be simulated so as to permit the performance of controlled experiments, rather than utilizing the purely random effects one finds in the open sea, the number of laboratory staff relative to the size of the fleet may be even larger. Not considered in these NASCO estimates are the additions of staff for other seagoing facilities; that is, special vehicles for exploration in the very deep parts of the ocean, as well as mobile (floating), anchored, or fixed stations (perhaps at the ocean bottom).

Detailed analysis of the program content, in terms of funds for research and for hydrographic surveying, also reveals an increase by a factor of between 3 and 4.

If the program has been designed to match the estimated needs for new knowledge of the sea, then in the aggregate an expansion by something on the order of 4 over the next 10 years rather than 2 is implicit in the proposals—expansion in funding, and in staff. This is essentially double the rate at which science and technology are now growing as a whole.

As compared to growth in space research by a factor of 4 in an interval of 3 years, this would not be a crash program. It is clear, however, from other indications, that this rate of expansion will not accrue if the present low rates of graduates and of funding continue.

The next question concerns the type of organizations in which expansion should occur. Will all of the growth develop in existing university and nonprofit laboratories? Will new organizations enter the scene, and, if so, what kind?

Regardless of whether the factor of 2 is selected for the degree of future expansion of oceanic research, or some larger number, there is question as to how and where this expansion is visualized as taking place with greatest effectiveness. There may be arguments raised that as a field of science, oceanography should grow unfettered by specific Government planning. But the fact that the Government will have a primary role of financial sponsorship generates a strong obligation to study the increased disbursement of public funds very carefully.

Performance components fall into two major categories: intramural and extramural organizations. Intramural laboratories represent those research organizations which are both funded and managed by Government agencies, with staffs who are predominantly civil servants. The extramural organizations represent the universities, nonprofit independent laboratories, and the industrial laboratories which conduct research for the Government on a contract or grant basis.

The question as to where the projected expansion should best take place was not discussed in the NASCO proposals. The TENOC report implied that the existing contract laboratories now performing research for the Navy would be earmarked for its expanded program. It is clear from the data presented in Section VIII, however, that a major part of the increase in effort is proposed to be sponsored by civilian organizations, rather than the Navy.

The possibility exists of accommodating and fostering growth by entirely new oceanographic laboratories that could either be Government owned and operated, or Government owned and contractor operated, following patterns established by the Atomic Energy Commission. Any study of this question may need a more penetrating appraisal of the place which Government laboratories do or should occupy in the national complex of research organizations, catering to interests which cannot await spontaneous generation at a university.

The question may also be raised as to how the greatly expanded fleet of oceanographic research ships should be operated. The NASCO reports were clear in suggesting that these should be placed completely at the disposal of those actually doing research, but manned by civilian crews so that the mission of the ships would not be diluted or distracted by other practical or military projects, and the ship captain have but one loyalty—to the chief civilian scientist. On the other hand, any such operation by research laboratories is inevitably a distraction to their main purpose of conducting research.

This question may not have evolved before since earlier oceanographic vessels took on the qualities of "yachts" and were thus far more manageable by the laboratories, and, by their small size, compatible with the laboratory mission.

There are thus three possible modes of ship operation. In the first instance, titles of new ships could be transferred to the laboratory user, and the research organization henceforth responsible for their operation with project funds. Another possibility exists for the operation of such ships, either for research or for survey purposes, entirely by agencies of the Federal Government, much as is now done. A third alternative which must be evaluated in terms of the relative economy and effectiveness of operation includes the use of commercial ship operators. In such cases, the United States would retain title to all of the new research ships proposed for construction, but their operation could be turned over in groups to independent organizations, whose sole purpose would be to cater to the oceanographic program. Control of the ships and payment of operating costs would still be the responsibility of the research laboratory, but by this means the ship operations, particularly of larger vessels, might be vested in organizations uniquely familiar with their operation and maintenance so as to free the research group from this problem.

Another important question relates to the development of data centers. The collection, indexing, filing, and dissemination of data ob-

tained through hydrographic surveying are activities over-ripe for development of special facilities and responsibilities, including the use of automatic computers. NASCO and the Government organizations concerned have urged establishment of a national data center at the U.S. Hydrographic Office.

However, the pattern of data centers established during the IGY may also be a factor in evaluating future growth of organizations performing research functions. During IGY, Texas A. & M. College which is an active participant in the national oceanographic program, was selected to be the U.S. custodian of all data collected by all national and scientific parties collaborating on the international program. The effectiveness of these data centers, and their future destiny have not been investigated, but the experience derived from their use should be instructive.

This leads to a question as to whether industrial laboratories fit into this picture in greater numbers than in the past.

In the main, industrial organizations have shown their strongest capabilities in the conduct of developmental projects, rather than research. Few have been able to attract the scholars who seem destined to remain in a university environment. Industrial laboratories may thus not be able to provide the talent required in the direct conduct of oceanic research. Relative industrial participation is suggested in Table 12.

On the other hand, industrial engineering concerns have capabilities to supplement skills in oceanographic laboratories for the design of special test facilities and vehicles that are visualized for the future. Industrial entrance into that area is also compatible with the more familiar pattern of an association of commercial interests with the sea in terms of new construction.

Expansion in the area of military oceanography, however, is a different matter. Technological advancement in antisubmarine warfare seems destined to grow, and the energies and imagination of solving practical problems of devices and systems may continue, as it has in the past, to be largely developed through contracts with industrial laboratories.

In brief, industrial interests in the sea thus relate most strongly to engineering ventures such as cable laying and off-shore drilling, to contract research in the area of military oceanography, and to the design and construction of oceanographic ships and vehicles. All of these developmental activities must draw on basic knowledge of the sea, in more or less degree. It can thus be argued that private industry has a stake in supporting oceanic research more than is presently evident, because it will become an immediate beneficiary of results of research. At the same time, industry has only limited incentives for investing their own funds in fundamental research in the oceans because it would be unreasonable to make such research proprietary; without such protection all organizations having access to the results would benefit and motivation would be diminished. On the other hand, all elements of those industries having an interest in the sea could pool their contributions for research through cooperative enterprises, a device frequently employed by trade associations, and used in considerable measure by such groups as the American Petroleum Institute. *If the universities and nonprofit research centers prove to be the focal points for oceanic research, their needs for increased facilities might be partially answered by endowments and contributions from those*

industrial concerns having interest in this area. Very little has been said in any of the proposals on means for stimulating financial support from industry in partnership with the Federal Government that was singled out as the primary source for future funding. Industry, in seeing its responsibilities to foster growth in a field such as oceanography, might wish to study this problem and develop their own proposals.

A great deal has been said about international cooperation. In the field of oceanography, it is evident that no dearth exists in terms of organizational framework for such activities. The question not fully explored in these proposals is the extent to which foreign scientists and laboratories may be fostered to increase the rate at which knowledge is developed of the oceans, thus supplementing what may be limitations in rate of growth within the United States. It is rather common belief that a dollar for research goes further in Europe, and studies might be made concerning the possible benefit of increased American sponsorship of research overseas. This would overcome natural objections by these nations to losses of their scientists to permanent employment in the United States. *Another possibility lies in the stimulation by the United States of other countries in the free world to accelerate their own internal programs in oceanography.*

The NATO organization has set up a European laboratory in La Spezia, Italy for the purpose of fostering oceanographic activities, and the success of this enterprise should be watched. In any event, considering the growth of the Sino-Soviet program in oceanography, there is likely to be need to enlist the scientific effort of the free world in ways not heretofore contemplated. This concept underlies much of the intent of international cooperation in outer space as set forth in the National Aeronautics and Space Act of 1958. However, only the more technologically sophisticated nations are likely to be able to participate with the United States in outer space. In oceanography, by contrast, many of the smaller nations could be interested in expanding or developing their own program on a cooperative basis.

B. PROBLEMS IN MANPOWER

Several comments in the NASCO reports and elsewhere refer to severe problems in recruiting, and note that the most unyielding limit on the rate of expansion would be availability of trained manpower.

To some extent, this appears based on extrapolations only of those receiving their education in the traditional lines of oceanographic research. Yet, as has been remarked previously, the marine sciences are a mosaic derived from the more basic disciplines of physics, chemistry, biology, from engineering, and more recently from the interdisciplinary fields of radiochemistry, biophysics, etc. Broad training in these fields does not equip these men with the very specialized knowledge that, for example, reflects a familiarity with biological life in the sea. But the methods of conducting geophysical research on the ocean floor seem likely to call upon the fundamentals that are developed even by nonoceanographers.

The same type of question arose when the United States desired to accelerate its atomic energy program and many engineers and even physical scientists shied away from a transfer to that field, simply out of concern that they lacked the necessary specialized knowledge requi-

site to making a contribution. After more publicity on the true content of the problems involved, materials engineers, for example, recognized the similarities between developing a structural metal that could absorb the fatiguing effect of alternating load while possibly degraded by the effect of neutron bombardment in the same way that in another application the degradation was brought about by effects of sea water.

Thus, at all levels of professional skills, if there is sufficient motivation, either through scientific challenge, job opportunities, salary, or some intangible such as the lure of the sea itself, there should be no insurmountable difficulty in expanding the numbers of professionals in marine sciences by transfers from other fields as well as by training new students—other fields for example, where relative emphasis may be diminishing.

According to Dr. James E. Lipp, of Lockheed Aircraft, who has been a member of the NASCO panel on new devices to explore the ocean:

> In my opinion, the estimate of the Committee on Oceanography—and here I am speaking purely as an individual—that the research effort can double in 10 years and reach a level about one-tenth of our present space effort, is very conservative.
>
> That estimate is based on the rate of training of new oceanographers, yet I am reminded of the space program which in a few short years has exploded from essentially no effort into a major profession.
>
> This has been done by drawing on industry for scientists and engineers, and can be done again in developing the oceans. It is only necessary to provide the same kind of funding and priorities that have been given to the space program.[95]

In historical perspective, future research administrators will probably agree that the crash expansion in space research has not been accompanied by the thrifty utilization of resources, either manpower or funds. But the fact remains, that prior to 1957, few engineers and scientists were concerned with affairs in outer space, and there is ample evidence that it attracted participants in large numbers, once the decision to embark on an accelerated program was made a matter of national purpose. By the benefit of advanced planning in oceanic research, losses in effectiveness during expansion could be minimized.

But robbing Peter to pay Paul is not the preferred solution to increasing numbers of trained manpower. Solutions to this problem considered by the NASCO Committee lie in simultaneously expanding the teaching facilities, and increasing the numbers of students who wish to make a career of oceanography.

H.R. 6298, now pending, singles out oceanography as a field in which applicants for fellowships may receive a priority for Government support over the general run of applicants. Although seemingly artificial in fertilizing this area, this procedure is probably more certain of success that if the otherwise random processes were allowed to continue. On the other hand, it has been argued that by singling out any special field for such attention, some side effects by establishing precedent might well cripple the remedy itself.

The far broader question about which many science administrators are tip toeing is whether, at any time, specific fields of science, deemed in the interest of national security, should be singled out for special attention. One of the rare examples of the approach has been the

[95] "Frontiers in Oceanic Research," op. cit., p. 72.

deliberate acceleration of radio astronomy in the United States by Federal grants for radio-telescopes, thus to regain a position of eminence once held by this Nation. Should the same philosophy apply to tailored stimulation of student interest? By allowing traditional processes to control, the normally democratic methods of treating all with equality would in time produce the needed staff. But in times of crisis or near crisis, there is a question as to whether other techniques must be exercised that are still quite far from the explicit assignment of Soviet young people into professional fields by Soviet government decree.

In many regards, the problem of attracting students to science as a career is a problem far transcending that of any single field; legislation has been addressed to the solution of the much broader problem, such as through the National Defense Education Act of 1958.

In oceanography, perhaps the most immediate problem is shortage of facilities for teaching, and this is one area that seems best destined for solution simply by increased numbers of grants. Most of the organizations catering to students in some branch of the ocean sciences derived their initial endowments for facilities from private sources. Certainly all of the universities today are communicating energetically with their alumni with one major problem in mind—overcrowded student accommodations. The Federal Government has been proposed in the NASCO reports as a source of the necessary funds, although the processes by which this can be accomplished are not entirely clear. Perhaps this area fits into the plan recently proposed by Dr. James A. Van Allen to the House Science and Astronautics Committee in urging new legislation patterned after the Hill-Burton measure that, through matching Federal-local grants, made possible the widespread development of medical research facilities and hospitals.

While on the question of manpower, it may be noted that while identifying the problem of manpower shortages, studies have not yet been extended into the area of possibly improved utilization. The NASCO reports did call attention to the ratio of Ph. D. to non-Ph. D. participation in the oceanic research program with the implication that larger numbers of staff at the bachelor and even technician level could contribute to research under the guidance of the more senior Ph. D. scientist. The number of Ph. D.'s to non-Ph. D.'s seems higher than in other fields of research, although these data are exceedingly difficult to interpret. Primarily, however, there may be changing patterns of the manner of doing research in oceanography as has occurred in other fields wherein the net total of quality-plus-quantity is enhanced by the use of professionals lacking a doctorate, but still able to contribute significantly.

C. PROBLEMS IN PROVIDING SHIPS AND FACILITIES

Except for problems in recruiting manpower, no item in any of the proposals for an accelerated program of research received greater attention than that of the need for additional ships, and for new ships to replace those overage and functionally obsolete now engaged in oceanography. With one exception, these ships are conversions, and a rather strong case has been made for their inadequacy. Former fishing boats, trawlers, patrol craft, minesweepers, and even pleasure boats are apparently unsuited for tasks at sea when making observa-

tions, and the index of their inefficiency is marked by the relatively large number of required crew compared to scientists.

Because these ships do not provide a stable, maneuverable platform for use in good or bad weather, the number of hours at sea available for observations is diminished. *Thus improvements in the research fleet would automatically be accompanied by an increase in effectiveness of the scientists—an event equivalent to an increase in their already scarce number.*

The design and construction of these special craft may provide a unique opportunity to experiment in naval architecture. Unlike the practice with aircraft, new ships, although designed from past experience, are expected to be successful as soon as constructed. With aircraft, on the other hand, a number of alternative designs on the drawing board may be screened for promise of success and several of them actually tested in the prototype stage. Then, the one judged best is placed in production. This opportunity to experiment in the aircraft industry permits trials of new ideas where the risk of failure is not fatal. Among other reasons, in not having that opportunity ship designers may be more restrained and conservative and new ideas very slow to evolve or be accepted.

Activity in the ship hydrodynamic field has reached a new peak in recent years, and a great deal has been learned in terms of increased efficiency, maneuverability, and stability amidst the random motions of the waves; new scientific results and engineering techniques have improved ship quieting.

There are obvious disadvantages of attempting to force an oceanographic research ship into the dual role of an experimental prototype for naval architecture; in trying to serve both functions, it may fail to serve either very well. Nevertheless, means might be sought to exploit this opportunity as a test of new ideas and concepts in hull form, steering, or propulsion, particularly those focused on the seakeeping properties. Any such measures, if successful, are sure to benefit oceanography; if unsuccessful, then very little may be lost.

Since part of the contemporary problem in rational design of ship hulls is the collection of statistical information about the sea surface, the coordination of research programs wherein these oceanographic vessels could be so utilized without sacrifice in their main mission has been mentioned.

In summarizing the problem concerning procurement of new ships, however, the main point in all of the proposals has been the long leadtime ever present between the appropriation of funds, and the design, construction, test, and readiness of the vessel for research. Thus, delays in funding for this purpose will ultimately create very severe, even if deferred, demands for far larger budgets—at least if the goals of the 10-year program are to be achieved. The failure to develop these funds thus far, even through fiscal 1961, is clear from the data presented earlier. The same problem seems to attend the need for shore facilities, for special vehicles for research at sea and the necessary logistic support vessels.

D. PROBLEMS IN FUNDING

It is interesting to note that whereas the 1951 NAS study of the state of oceanography in the United States recommended that addi-

tional support be sought from private sources while the Federal sponsorship be maintained essentially constant, the 1959 study emphasizes growth in support almost exclusively from Federal funds; only a passing reference is made to additional support from endowments and other private sources. None of the projections in the NASCO studies anticipates increases from any source but the Federal Government. Neither, apparently, do studies by the Interagency Committee on Oceanography.

The emerging role of the Federal Government in the sponsorship of a national program in science and technology is generally acknowledged. Furthermore, oceanography is not a field that has thus displayed sufficient promise of direct "payoff" as to attract private risk capital, however important it may be to the Nation collectively. In the first instance, the fisheries that would most immediately benefit are apparently not in a sufficiently prosperous or well-organized position to foster more research. Secondly, other nonfishery gains appear too remote.

But are they really? Studies of substance are almost completely lacking regarding either the promise for commercial exploitation of the sea or the mechanism by which this could be fostered. Such a study would go far to reveal profit potential as well as means by which the Government, through incentive programs and seed capital, could interest industry in undertaking more research on its own.

The petroleum industry with its own funds has undertaken exploration of the offshore resources of oil and natural gas. The costs of such exploration and the development of wells have been found to be marginal in the present market. But the need for eventually pressing further offshore into deeper water and developing techniques for developing new resources is a certainty in an era when reserves of fossil fuels are being depleted.

The Federal Government through various means has fostered such exploration in the past, and special incentives such as might prove attractive for adventures into deeper water could possibly stimulate a great deal of then self-sustaining offshore activity. Although beyond the scope of the NASCO Committee assignment, such an analysis is certainly within the province of one of the executive agencies having jurisdiction in this area.

In the meanwhile, the recommendations for funding are aimed at Federal agencies. *It should be especially noted, however, that although the Navy has had a dominant role in the past, these plans anticipate a sufficiently fast growth of sponsorship in the civilian agencies that by 1970, they, not the Navy, will be taking the major share of sponsorship.*

Finally, the oceanographers point out that Federal support is a mixed blessing. Entirely apart from the degree to which Government as a sponsor must and should control the technical content of research programs, there is the ever-present threat of intermittent and unsteady support.

Assistant Secretary Wakelin noted that in the past 5 years, during all of which the Navy had a prime responsibility in studies of the sea in connection with the ASW program, funding has been increasing, but not in a fashion that would give directors of independent laboratories a feeling of security. In 1957, funding was $6 million. In 1958, it dropped to $5.7 million. Since then it has increased

steadily until for fiscal year 1961 it is projected for $17 million. A glance at Table 28 reveals an uneven record of naval support, especially considering shrinkage of research effort during intervals of inflation.

TABLE 28.—*Navy funding for conduct of oceanographic research, 1951–61*

[Millions of dollars]

Fiscal year	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Appropriations	[1] 5.5	[1] 4.3	[1] 5.2	[1] 4.1	[1] 5.1	[1] 7.9	[2] 6.0	[2] 5.7	[2] 7.5	[2] 9.1	[2] 17

Source:
[1] "Oceanography in U.S.," op. cit., p. 138 (Rear Adm. John T. Hayward).
[2] "Frontiers in Oceanic Research," op. cit., p. 63. Lack of agreement with Navy data in Tables 13 and 14 is probably due to different definitions of oceanography.

E. COORDINATION OF FEDERAL PROGRAMS

It is clear that the Federal Government now plays a dominant role in the support of oceanographic research that is showing signs of increasing. Especially if the program should expand by a factor of four as recommended by all of the studies thus far, effectiveness in coordination of the different elements is critically important to its success. With various Federal agencies now having statutory jurisdiction over these separate elements, coordination on a formal basis has been recommended by a number of the witnesses appearing before interested committees of the Congress, as well as by those having administrative responsibility. As has been said previously, there is widespread agreement on the need; differences in viewpoints arise on the mechanism.

Before examining various methods of coordination, present and proposed, it may be helpful to the reader to examine the fundamental proposition of the objectives of such coordination. Omitting the more obvious generalities, the goals of coordination in the context of oceanic research may be said to include:

(*a*) Definition of a single national program in oceanography, including a statement of purpose, the long-term plans by which that objective may be achieved, including the delineation of the various sectors of the program represented by interests or jurisdiction of the different agencies which in the aggregate identify a single Federal program;

(*b*) Formulation of a single Federal budget, broken down by agency and by function, representing the funds required for research, for surveying, for new ships and facilities;

(*c*) Procedures for following up these various programs to be sure that the intended balance is achieved, and that none suffers from want of vigorous leadership, funds or program that would prejudice the broader goals;

(*d*) Standardization of methods of collecting and tabulating data and means for exchange of data so that duplication is minimized, and the best possible use made of what is collected;

(*e*) Coordination in planning of cruises to take every possible advantage of research ships simultaneously serving scientific needs of several organizations.

(*f*) Detailed coordination of programs to be sure that unknowing duplication in the conduct of research is minimized and, at

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the same time, that no portion of the program goes undeveloped because of misunderstanding by all organizations that responsibility was in another's hands;

(*g*) Cooperation in the development of needed manpower, through fellowships, grants, etc., including information and procedures that would minimize "raiding";

(*h*) Coordinated use of advisory committees such as the Committee on Oceanography of the National Academy of Sciences, and other groups so that separate panels would not be unnecessarily developed to advise narrow interests of particular Government agencies that could as well or better be served through the use of a smaller number of outside groups, jointly serving the Government interests (such as was done in the case of the NASCO study).

The responsibility for coordination is presently placed by executive action on the Interagency Committee on Oceanography, under the Federal Council for Science and Technology. This organization serves in an advisory capacity to the President and has no statutory basis for its responsibilities. The presence of any such organization in the political climate of the President's office thus suggests some inherent uncertainties about permanence and continuity.

A far more basic question lies in the strengths and weaknesses of any interdepartmental committee as a device for coordination. Problems in this regard have been highlighted by a comprehensive study of such committees by the Brookings Institution, relevant sections of which have been quoted as a basis for understanding some of the problems that may beset the ICO.[96]

> The methods for bringing together points of view and for securing decisions on matters of interest to several agencies can in general be classified into two main groups, within each of which various subdivisions can be distinguished. One group of methods is essentially *voluntary* in character, and relies mainly upon cooperation among the agencies concerned, however such cooperation is organized. The other group of methods looks to the *exercise of higher authority*, and relies mainly upon processes of organization and staff work that will prepare matters for decision and bring them before an appropriate higher official, in many cases the President. The voluntary methods range from the most informal of relationships between agency personnel to the formal establishment of interdepartmental committees whose terms of reference are imbedded in statute law. The methods based on higher authority may similarly vary from the gentlest kind of persuasive comment by members of a higher official's staff to the issuance of a formal command in the form of an Executive order, backed by the President's authority to remove from office if final disciplinary measures become necessary.
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> In some respects, the use of interdepartmental committees may have the effect of qualifying executive responsibility. The traditional approach to United States Government organization and procedure is to divide responsibilities among executive departments, and to assign full authority to them. To the extent that it is possible to make clear jurisdictional assignments, interdepartmental committees would perhaps not be necessary. But actual problems do not ordinarily arise in separate and clearly divided categories.
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> Experience seems to show that there are situations where a formally organized committee provides a useful framework for purposes of coordination. Nevertheless, there appears to be a need for more care in the establishment of committees, to limit their scope to matters on which they can be expected to be productive, to insure better performance when they are necessary, and to prevent

[96] "The Administration of Foreign Affairs and Overseas Operations," June 1951, Brookings Institution (prepared for Bureau of Budget), pp. 327–360.

them from being established merely to forestall other forms of action that might be more effective.

The potentialities of the committee device require testing by analysis of existing experiences, after which there will be more of a basis for determining the extent, if any, to which it should be preferred to other measures for securing coordination.

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There are a number of specific issues that bear directly upon the potentialities of the interdepartmental committee. The first and most fundamental is that of the types of activity that can appropriately and effectively be carried on through interdepartmental committees. A second is that of what to do to secure a decision in those cases where, after consideration of an issue, a committee finds itself deadlocked. A third, closely related to the previous two, is that of the level in the governmental hierarchy at which committees should normally be established for maximum effectiveness. A fourth has to do with the method of establishing and discontinuing committees; a fifth with where responsibility shall be fixed for the administrative supervision of committees, if it is agreed that there is a need for such supervision; and a sixth with the question of how committee secretariats shall be provided. Several of these issues arise on every occasion on which the establishment of an interdepartmental committee is considered.

Issue 1: (a) Types of activities

It may be useful for analytical purposes to state a range of alternatives that reflect a spectrum starting with substantive policy at one end and detailed administrative activity at the other. If this is done, the major positions or alternatives along the scale might be somewhat as follows: (1) The formulation of substantive policy, the drafting and adoption of policy papers, and the review of the implementation of policy; (2) responsibility for program planning and review, including the framing of program proposals, adoption of program plans, and review of program performance; (3) responsibility for preparing proposals for presentation to Congress and instructions for negotiations with other governments; (4) responsibility for determining the assignments to be made to the various participating agencies in carrying out agreed programs of action, including the settlement of such incidental jurisdictional questions as may arise; and (5) responsibility for coordinating and controlling program administration in detail when it is necessary to carry on a program through the joint activities of several agencies.

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Moreover, although the usually cumbersome nature of a committee may be thought to restrict its usefulness in the formulation of broad new programs or policies, a committee can more easily perform the almost equally important function of *review of policies and programs.* Here there is no necessity for opening up broad new vistas; the question is only one of what is to be seen at the end of the vista; and yet the policy problem is an important one, and is the kind of problem on which the views of a variety of agencies may be of real assistance.

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Issue 2: Appellate procedures

Effective operation of an interdepartmental committee depends upon some method of breaking possible stalemates in the committee. Inability to resolve committee differences may lead to reconciliation of views on the basis of the lowest common denominator, or to a postponement of decision, perhaps until the issue is settled by inaction. In addition, it is possible that the primary responsibilities of an agency may be seriously affected by its inability to get a firm decision from an interdepartmental committee on a matter related to the area of its responsibility. The poor reputation of interdepartmental committees among governmental officials is largely attributable to the frequent absence of a clear method of compelling a decision in the event of deadlock.

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While it is true that an individual with some shadow of Presidential authority can sometimes mediate in situations where committees cannot agree, the fact is that the recurrent use of the interdepartmental device is based on the need to bring together the views of a number of agencies plus a distrust in most

agencies for Presidential staff work that disregards agency interests. Staff work at the Presidential level is likely to be successful only if it is supplementary to interdepartmental coordination of most issues before they come to the Executive Office.

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Issue 3: Level of committee establishment

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The principal levels that come under consideration when a committee is to be established are as follows: (1) at the Cabinet level; (2) at the Assistant Secretary, or sub-Cabinet, level; (3) at the chief of bureau or office director level; and (4) at the chief technical and professional level.

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Issue 4: Method of establishment and discontinuance

What should be the method by which definitive action is taken to establish interdepartmental committees, to specify their membership, functions, and authority, and when necessary to dissolve them?

Practice as to the method of establishing interdepartmental committees has been extremely varied. A conflict is often present between the desire to keep coordinating machinery flexible, so that it can be adapted to changing needs, and the desire to achieve the utmost in prestige and status for the committee's work. Those who favor flexibility will work for informal means of establishment. Those who desire special status usually favor formal means of establishment, including establishment by statute, if possible.

The four principal alternative methods of establishment are (1) by interagency agreement in writing; (2) by Presidential letters; (3) by Executive order; and (4) by statute; the method of discontinuance would usually depend on the method of establishment if the act of discontinuance is to be a definite one.

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As between Executive order and Presidential letter, the main difference is procedural, since either would involve Presidential action to establish a committee. The Executive order method automatically results in a channeling of the proposal through a clearance process before it comes to the President for action. Higher standards of draftsmanship are likely to be imposed, and any statement as to the terms of reference of the committee would be certain to have been carefully considered. The same results would be attained for Presidential letters processed through the same procedure; but if the sponsors of a proposed committee are given their choice, they may quite possibly choose the Presidential letter as the action instrument in order to escape exactly those procedural safeguards that have been thrown around the issuance of Executive orders.

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General considerations affecting committee usefulness

The committee device is most workable when the committee can be made advisory to one agency, which other members of a committee accept as having the primary action responsibility for matters coming within the committee's purview. This arrangement, when it is possible to recognize a clear leadership responsibility in one agency, tends to minimize the unanimity principle and to allow work to proceed more rapidly.

The reason why committees advisory to an agency of primary interest work best in the American system is that committees of this type do least violence to the line of command and executive responsibility. Jurisdictional issues under these circumstances are not likely to plague the work of a committee, and it remains the responsibility of the agency most involved to accept or reject the advice given. Experience seems to indicate that in the great majority of cases, the agency with primary responsibility has been willing to accept and utilize such advice.

Much of the difficulty that has been experienced with committees has developed in cases where primary responsibility does not reside clearly in any single agency, where the terms of reference of the committee are not clearly defined, or where some members of a committee are attempting to use it to enlarge their own sphere of responsibility.

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Even within these terms, the interdepartmental committee should not be considered a panacea for interagency ills. In many cases, informal liaison will be a more effective and less costly way of fixing policy or administering or reviewing programs. In other cases, the remedy for diffusion of authority may lie in the concentration of authority in a single agency, rather than in institutionalizing relations between agencies of divided authority by establishment of a committee.

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There are probably several hundred interdepartmental committees of one kind or another now functioning within the Federal Government, and with such numbers, considerable variability may be expected in their effectiveness. Writing on this topic, F. M. Marx noted that—

> * * * it cannot be said that there is a comprehensively interlocking committee system, built upon objective standards of need. Nor should one expect too much from it if there were such a committee system. In the nature of things, interdepartmental committees seldom feel a directing push from above. They function on condition of agreement, and may deteriorate into trading posts where stubborn parties bicker for their own advantages. Apparently, such committees work best on the basis of specific terms of knowledge to ease mutual commitment, and under alert and vigorous leadership. When these conditions prevail, interdepartmental committees may repay many times the administrative effort invested in them.[97]

An outstanding example of effective interdepartmental coordination through committee operation is the Interdepartment Radio Advisory Committee which coordinates telecommunications policies and standards, and assigns frequencies for use of all radio transmitters in eleven departments of the executive branch which comprise the primary Federal users of the radio spectrum. In this regard, the IRAC is essentially a Government agency which parallels the Federal Communications Commission in having authority over Federal transmitters while the FCC has authority over all non-Federal radio operations.[98]

Apart from representing a means for interagency coordination, the resemblance between ICO and IRAC disappears.

A number of alternative methods for interdepartmental coordination are listed in the following, including the presently established committee plan:

(1) Interdepartmental committee, with representation at senior levels of management from the agencies most concerned with oceanic research—

(*a*) Established by new legislation

(*b*) Established by Executive order (as is the case with the ICO)

(2) Formation of a new, special coordinating agency (such as the Office of War Mobilization, instituted in 1943 to unify activities of numerous agencies concerned with production, procurement, and distribution of military and civilian goods).

(*a*) Established by new legislation

(*b*) Established by Executive order

(3) Assignment of the coordinating function to a single Department having existing jurisdiction over a major segment of oceanic research, with program and budget planning established through an inter-

[97] "Elements of Public Administration" Fritz Morstein Marx, 2d edition, Prentice-Hall, 1959, p. 180.
[98] IRAC is located in the Office of Civil and Defense Mobilization and acts for the OCDM in the matter of Federal telecommunications in accordance with the National Security Act, sec. 103(c), as amended, and implem ented by Executive Order 10460 of June 16, 1953.

agency committee acting in an advisory capacity; the agencies having jurisdiction over various programs would continue but senior responsibility would be vested in a single organization.

(4) Assignment of the coordinating functions to two agencies, separated as in the case of space research into military and nonmilitary entities (if indeed that could be done in the case of oceanographic research).

(5) Assignment of coordinating functions to a quasi-governmental body such as the Smithsonian Institution or the National Academy of Sciences.

(6) Establishment of a new organization having both coordinating and operating responsibilities for all sectors of the oceanic research program, except the basic and applied programs having distinct military applications (following the precedent of the National Aeronautics and Space Administration).

(7) Establishment of a new organization having both coordinating and operating responsibilities for all sectors of the oceanic research program, including all basic and applied research for either military or civilian application, excluding development (following precedent of the Atomic Energy Commission).

It is beyond the scope of this present report to delve further into the various merits and problems of each. Obviously, none is a panacea.

The relative performance, however, can be measured in terms of the capacity of the agency to make decisions—for, indeed, this is often cited as the primary role of a Government agency. It may carry out some of these decisions as well, but in oceanography, at the present, most of the research is being accomplished on contract. Surveying, however, is retained as an operating function.

This problem of administrative control of the oceanographic program was reiterated by the American Association for Advancement of Science:[99]

> When the organized effort to increase federal support for oceanography began about 3 years ago the science faced two especially important obstacles: it was popularly regarded as a field about as far removed from practical affairs as astronomy, and it faced a peculiar organizational problem in that the various elements of oceanographic research were fragmented among a dozen or so different government bureaus and agencies. As a result, although a growing number of people began to recognize that it was in the national interest to develop much enlarged support for the science, the fragments of the program scattered through the Navy, Interior, Commerce, and other departments and agencies tended to be little noticed in the over-all functions of the agencies and in their budget making.
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> Organizational Problems
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> It is the publicity that all these things have received from the NAS–NRC report and the other forces at work that have led to the increases in support for the science. But assuming, and opinions vary on this, of course, that oceanography has now achieved a proper degree of support in relation to other scientific programs, the question is raised whether this rather makeshift, basically political, method of rallying support for oceanography is really satisfactory and efficient. It is tempting, in situations like this, to seek some organizational cureall, and advocates of a cabinet-level Department of Science sometimes

[99] "Science," May 27, 1960, vol. 131, No. 3413, American Association for the Advancement of Science, pp. 1592–1593.

point to an area like oceanography as an outstanding example of where such a department could function to establish priorities in various fields of science and to organize support in a more straightforward and less time-consuming method than had to be used in this case.

Indeed, several of the scientists who appeared before the Jackson committee this month, while opposing a Department of Science, suggested that in the case of areas like oceanography, which are so fragmented that there is no one who really feels responsible for the area as a whole, the National Science Foundation might be used to present a unified program to Congress and then distribute the appropriations to the operating agencies, as it now distributes research funds to nongovernmental agencies.

This would alleviate the sort of problem that was run into when the House subcommittee handling Commerce Department appropriations cut out the $300,000 of the over-all program assigned to the Weather Bureau. To this subcommittee the Weather Bureau is only a minor function of the Commerce Department, and when they began looking for things that could be cut it is not surprising that they questioned the necessity of the Commerce Department supplying the Weather Bureau with funds to do research in the ocean.

A considerable amount of effort, both in the executive and in Congress, has been going into such organizational improvements. In fact, there is a good deal of experience that suggests that more organization, by removing authority one degree further from operating responsibility, often succeeds only in further complicating the problems it was intended to cure. So the desire to seek organizational solutions is tempered by the recognition that there is a limit to the degree to which neat organization charts can really solve administrative problems.

The problem of diffused organization is no less serious when the Congress is faced with evaluating different programs of different departments, and with the corresponding appropriations. The vast number of Government bureaus enumerated previously all become the subject of responsibility of a wide number of congressional committees.

Equally important, the legislative branch in its function of monitoring the executive branch might desire to hold one particular organization rather than a large number responsible, particularly if the area is one deemed in the national interest by the Congress as needing acceleration. To crystallize a coherent program out of the sum of the various parts holds enormous potential for frustration. There are questions as to whether the Congress could hold a panel or sector of the FCST to account in matters of this kind, in view of the special position that the FCST holds, vis-a-vis the Executive, and the reluctance of any Executive to forgo executive privilege by making his staff activities freely available to the Congress.

XI. Oceanography as an Element in a Federal Program of Science and Technology

The following three brief sections are intended to provide the reader with additional background information and frames of reference for use when evaluating any program in science and technology and, in particular, one visualized for oceanography. The first section contains a brief summary of objectives for national policies in science; the second concerns some recent statements on innovations in Federal organization for science including that of Federal support of oceanography; the third contains a specific example of Federal sponsorship of Antarctic research.

A. National Policies in Science

These efforts have been made in many places—in the executive branch, in Congress, in international organizations, and wherever our scientists do their work. They have been directed at multiple objectives:

To enhance the excellence of our science, both basic and applied, and to add to our effort, relatively, in basic research;

To extend the recognition of science as a creative activity that augments man's dignity and understanding and affords him intellectual adventure of the highest order;

To recognize that outstanding accomplishments in science appeal deeply to the hopes and aspirations of men everywhere, and contribute to the prestige and good will of nations;

To demonstrate that the democratic environment of the free world is the best environment for achievement in science;

To improve the ways in which our Government uses and supports science;

To apply it more effectively to improve our environment, to strengthen our economy, to improve the health and welfare of our citizens and the peoples of the free world;

To promote international understanding and good will;

To insure that science and technology contribute their maximum to the defense of the United States and the free world.

I pause to recall these objectives because the campaign in which we are engaged to strengthen science and use it wisely must embrace them all if it is to achieve full success.[100]

B. Federal Oceanography—Coordination or Centralization

From the list of agencies of Section VI, it is clear that responsibilities in the field of oceanography are now vested in a number of different Federal agencies, automatically entailing the requirement of coordination. At present, this is effected through the Interagency Committee on Oceanography within the Federal Council for Science and Technology. A number of alternatives have, from time to time, been proposed.

In an address on national science policy to The Johns Hopkins University, Dr. Lloyd V. Berkner surveyed the responsibilities and problems of Federal sponsorship of research and endorsed a new Federal Department of Science and Technology. He visualizes this

[100] Report of Dr. James R. Killian, Jr., to the 125th national meeting of the American Association for the Advancement of Science, Dec. 29, 1958, published in Senate Rept. No. 120, pp. 3–4.

as specifically suited to "Government scientific and technical services not principally involved in existing department objectives or strongly related in the organic sense to the functions of a single Federal Department, but of the utmost importance to the Government and people as a whole." [101]

Dr. Berkner stated that in this category responsibilities are not now, nor can be, well discharged by Government:

(1) since the agencies concerned * * * are stepchildren of considerable nuisance value to their individual departments
(2) the organizational division * * * prevents collaboration
(3) these agencies are at a vital disadvantage in obtaining budget support in competition with other bureaus not closely connected to individual departmental objectives
(4) since these agencies are minor departmental responsibilities, departmental heads have little knowledge of their real importance. * * * Certainly such a department would include the following divisions:

1. Physical Sciences and Standards
2. Oceanography
3. Meteorology
4. Resources
5. Scientific and Technical Information
6. Mapping
7. Time, Geodesy and Astronomy
8. Continental Fish and Wildlife
9. Radio and Outer Atmospheric Research
10. Polar Activities [102]

Somewhat similar proposals, although perhaps less specific, have been advised by Dr. Wallace Brode, science adviser to the Secretary of State:

1. There should be a regrouping of some of the Government's scientific agencies or activities: either a Department of Science, a National Science Institute, or some other coordinated structure. A well-developed coordination must be established between the regrouped combination and those scientific agencies which remain separate, so as to insure an efficient and comprehensive national science program.
2. There should be a realinement of the distribution methods and responsibility for support of basic research in our educational institutions, with a movement toward university grants, administered largely by a department concerned with basic research, rather than by agencies concerned with applications. This may well need to be coordinated with the growing problem of support for our advanced-education program in all areas.
3. There should be some separation of governmentally sponsored, major research institutions from our educational and industrial system, especially of those institutions which are essentially concerned with applied science. There should be a greater acceptance of the idea of operation of such institutions under an improved, directly governmental administration.
4. The liaison of scientists in government with scientists in the academic field and in industry should be represented by a National Science Council in such a manner as to be compatible with the maintenance of our broad culture and balanced development.[103]

Legislation focused in this direction was introduced through the Science and Technology Act of 1958 (S. 3126) and a considerable amount of testimony has been offered concerning the effectiveness either of a central Department of Science and Technology or of the use of national institutes. A modified form of the bill was introduced in the 86th Congress by Senator Hubert H. Humphrey (S. 676), but at this writing it had not been acted upon.

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[101] "Science Program—86th Congress," S. Rept. 120, by the Subcommittee on Reorganization and International Organizations, Committee on Government Operations, March 1959, p. 117.
[102] Ibid.
[103] "Development of a Science Policy" by Wallace R. Brode. Science, vol. 131, No. 3392, Jan. 1, 1960, pp. 9-15 (presidential address by Dr. Brode on Dec. 28, 1959, during 126th annual meeting of AAAS, in Chicago, Ill.).

C. FEDERAL SPONSORSHIP OF ANTARCTIC RESEARCH

Although no direct analogy exists insofar as research management is concerned between the conduct of research in the Antarctic, and that in the oceans the manner in which the Antarctic program has been sponsored may be of interest.

The most recent systematic exploration, beginning in 1956, was coordinated with the much broader program of the International Geophysical Year (IGY). Actually, this is the third such scientific undertaking and was preceded by international studies of the North Polar regions in 1882–83 and 1932–33. The decision to hold a third such period of observations after a lapse of 25 years is based, to a great extent, on the intervening technical progress and the shift in emphasis to the geophysical study of the entire Earth. The 1957–58 date, incidentally, for the IGY was chosen because it was expected to coincide with the maximum in the 11-year sunspot cycle.

Action which stimulated this program began in 1950 during informal meetings of scientists in the United States. Formal proposals were submitted to the International Council of Scientific Unions (ICSU), which in 1952 set up a special committee to coordinate the IGY (July 1, 1957 to December 31, 1958). In brief, the organization of the International Geophysical Year was a nongovernmental, although worldwide, effort carried out by scientists through their national and international organizations. Participation by the United States with ICSU has been through the National Academy of Sciences which, beginning in 1953, formed a National Committee for the International Geophysical Year (USNC–IGY). Detailed planning for the Antarctic program was begun in November 1953.

The National Academy of Sciences participated and cooperated in the planning and obtained special funds from the Congress for this purpose, beginning in 1954, with a budget of $13 million. In 1955–56, the Congress granted additional funds, primarily to mount the Earth satellite program, for an estimated total of $39 million.[104]

The Antarctic phase of the program was formed under the direction of Dr. Laurence M. Gould and Dr. Harry Wexler, who chaired the particular Committee of USNC–IGY concerned. It worked closely with the Department of Defense as well as polar operations groups at the Weather Bureau and coordinated the U.S. activity with that of other countries.

At the conclusion of this IGY expedition, it was recognized that further scientific observations in the polar regions should be continued for scientific as well as political reasons. Following recommendations by the USNC–IGY, other scientific committees and by the House Committee on Interstate and Foreign Commerce, the National Academy of Sciences formed a Committee on Polar Research, early in 1958, to take over the full operations of the Antarctic program.

Later in 1958, however, these same responsibilities were then transferred to the National Science Foundation which had established a U.S. Arctic program (USART). The program is now continuing under NSF auspices.

Some further details of the responsibilities of the different organizations having cognizance of this Arctic research follow. In the first

[104] "International Geophysical Year, the Arctic and Antarctic," H. Rept. 1348 of the Committee on Interstate and Foreign Commerce, February 1958, p. 11.

instance, from 1953–57, when IGY began, the responsibilities for planning were vested in the USNC–IGY completely fostered by the National Academy of Sciences. This IGY Committee had full responsibility for planning all aspects of the scientific program, including its administration, fiscal management, and logistic support. Funds were provided through the National Science Foundation.

When the Committee on Polar Research succeeded the IGY Committee, these responsibilities were undertaken on behalf of the National Science Foundation by the National Academy of Sciences. In the main, however, logistic support was arranged through the Navy which, at that time, was providing the necessary logistic support at DOD expense rather than that of the Committee on Polar Research (from the National Science Foundation). Many of the same staff from IGY continued with the CPR.

This activity, however, was not consistent with the normal functions of the National Academy of Sciences which, with the exception of such unusual circumstances as the IGY itself, does not engage in scientific operations, but rather serves in an advisory capacity to the Government. It is for this reason that in 1959 the Academy divested itself of Antarctic responsibilities and the National Science Foundation, consonant with its statutory requirements, accepted the full responsibility. Many of the same CPR staff also transferred to the NSF so that some continuity in program and management was maintained.

At the present time, the National Science Foundation has overall program and budgetary responsibility, although it solicits advice from the National Academy of Sciences, regarding both national programs and policies. The Academy is responsible for international cooperation through SCAR, the Special Committee on Antarctic Research, set up under ICSU at the conclusion of the IGY.

Logistic support, incidentally, is still to a great extent provided by Navy Task Force 43 and there is every expectation that the responsibilities for a U.S. program in the Antarctic will continue through NSF.

That some uneasiness has developed concerning the effectiveness of the current program is revealed in a statement by Representative Clement J. Zablocki, of Wisconsin, appearing before the House Committee on Interior and Insular Affairs, June 13, 1960, and speaking on behalf of a bill, H.R. 5222, concerned with the establishment of a commission to plan, develop, organize, coordinate, and direct Antarctic activities:

> I am certain that you will agree with me, Mr. Chairman, that United States activities in that vital region have been conducted by a number of offices, agencies and Departments, many of them achieving outstanding results in their own efforts. What has been lacking, however, is a coordinated continuing and consistent interest in the Antarctic. We have no long-range plan which would advance our national interest in that continent. We have no coordinated support of study, research and development of programs for peaceful uses in science, commerce and other activities related to Antarctica. Our plans and undertakings have been sporadic, discontinuous, and lacking in clearness of purpose.

With a change in only one or two words, this statement may be found to match those of witnesses appearing before other Congressional committees in support of pending legislation in oceanography.

XII. Legislation Pending Before the 86th Congress

The Congress has had a continuing interest in affairs concerning the sea, in the main pursued by following normal activities of executive agencies having jurisdiction over various sectors of oceanic research. The same may be said to be true insofar as congressional responsibilities are concerned for the appropriation of funds and overseeing their expenditure.

Soon after release of the National Academy of Sciences report in February 1959, however, deficiencies which were attributed to the current level of effort, and proposals for remedy came to the attention of the Congress. With relationships drawn of oceanic research to the national security, the implications for Federal spending and for interagency coordination or jurisdiction, the Congress recognized that the problem demanded its early and intensive study.

Almost immediately, the House of Representatives, through the Committee on Merchant Marine and Fisheries, established a new Subcommittee on Oceanography under chairmanship of Representative George P. Miller. Other standing committees in the House, in particular that on Science and Astronautics, and in the Senate, particularly that of Interstate and Foreign Commerce, also began deliberations.

The Subcommittee on Oceanography began an extensive set of hearings on March 3, 1959, and lasting through June 2, 1959, to develop background information in more detail on the basis of which the most prudent course of action could be recommended.

In April 1959, Representative Overton Brooks introduced H.R. 6298, the first of a number of bills which in timing and content may be regarded as having been stimulated by the NASCO report. This bill would amend the National Science Foundation Act of 1950 so as to foster teaching facilities and graduate study in the field of oceanography as a direct means of relieving the shortage of manpower pinpointed by NASCO as the most serious limiting factor in any program expansion.

In June of 1959, Senator Warren G. Magnuson introduced Senate Resolution 136, presented earlier, that sets forth in strong and forceful language the interpretation which the Senate placed on the importance of oceanography to national security and the intent of the Congress that prompt and planned solutions be made a matter of national policy. The resolution passed unanimously.

Then, in September, Senator Magnuson, speaking for himself and 13 other Senators, introduced S. 2692 which may be regarded as an omnibus bill "designed to implement the major recommendations of the Committee on Oceanography calling for a comprehensive 10-year program of oceanographic research and surveys." [105] It was referred to the Committee on Interstate and Foreign Commerce. Hearings were convened April 20–22, 1960.

[105] Opening statement by Senator Magnuson on hearings of S. 2692, on April 20, 1960.

A corresponding bill, H.R. 9361, was introduced by Representative Thomas M. Pelly before the House of Representatives in January 1960. It was referred to the Committee on Merchant Marine and Fisheries, and under the Subcommittee on Oceanography extensive hearings on its merits were held May 17, 19, 20, 24, and 25, 1960.

A number of related bills concerned with other segments of research or activities in the sea have developed during the 86th Congress, including—

H.R. 9584, concerned with disposal of dangerous articles at sea.

H.R. 8611, to remove geographical limitations of the Coast and Geodetic Survey (following S. 2482). Passed, as amended, April 5, 1960 (P.L. 86–409).

H.R. 8612, to provide flexibility in operation of the Coast and Geodetic Survey and Weather Bureau.

H.R. 10412, H.R. 10546, and H.R. 10581, for the coordination of oceanographic surveying among different executive agencies.

H.R. 10645, concerning amendment of the Merchant Marine Act.

H.R. 12018, concerned with the establishment of a national center for oceanographic data, and for instrument calibration.

The preambles and, in some instances, pertinent sections of the extent of these bills follow:

86TH CONGRESS
1ST SESSION

H.R. 6298

IN THE HOUSE OF REPRESENTATIVES

APRIL 13, 1959

Mr. BROOKS of Louisiana introduced the following bill; which was referred to the Committee on Science and Astronautics

A BILL

To amend the National Science Foundation Act of 1950 to provide financial assistance to educational institutions for the development of teaching facilities in the field of oceanography, and to provide fellowship for graduate study in such field

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the National Science Foundation Act of 1950 is amended by redesignating sections 15, 16, and 17 as sections 16, 17, and 18, respectively, and by inserting after section 14 the following new section:

"ASSISTANCE TO EDUCATIONAL INSTITUTIONS AND GRADUATE STUDENTS FOR THE TEACHING AND STUDY OF OCEANOGRAPHY

"SEC. 15. (a) (1) The Foundation, in carrying out its function of promoting education in the sciences, is authorized to make grants to accredited nonprofit institutions of higher education to assist them in carrying out programs for the acquisition and development of facilities for the teaching of oceanography.

"(2) To be eligible for a grant under this subsection, an institution of higher education must submit to the Foundation an application setting forth a program, for the acquisition and development of new or additional facilities for the teaching of oceanography, which meets standards established in regulations prescribed by the Foundation. Such application shall contain adequate assurances that any grant under this subsection will be used only for faculty salaries, equipment, and other expenses arising from or attributable to such program, and that the institution will comply with the regulations prescribed by the Foundation to carry out this subsection.

"(3) Grants under this subsection shall be awarded in such amounts and to such institutions as will result, in the judgment of the Foundation, in the most rapid and effective expansion of facilities for the teaching of oceanography at all appropriately located institutions throughout the United States, giving particular consideration to institutions which can provide for their students who are

studying or preparing for study in the field of oceanography the most well-rounded education in the related basic sciences and the practical advantages of affiliation or association with marine laboratories and other related research organizations.

"(4) The regulations prescribed by the Foundation to carry out this subsection shall include provisions designed to insure that such grants are used only in the manner and for the purposes set forth in this subsection, but shall not otherwise provide for or permit any interference with or control of the faculty or curriculum of any institution to which such a grant is made.

"(5) In the event of the failure of any institution of higher education to comply with the regulations prescribed by the Foundation to carry out this subsection, the Foundation may terminate or suspend any further payments to such institution under this subsection.

"(b) (1) The Foundation, in carrying out its functions set forth in section 3(a)(4) and to assist in meeting the need for increased numbers of qualified oceanographers, is authorized to award graduate fellowships for study in the field of oceanography. Except as specifically provided in this subsection, such fellowships shall be awarded in the manner and subject to the conditions provided in section 10 and the regulations prescribed by the Foundation thereunder.

"(2) The fellowships provided for in paragraph (1) shall not exceed eighty (which shall be in addition to any fellowships awarded under section 10) in any one year, and any such fellowship shall be available only for enrollment in a graduate program of study in oceanography, for an aggregate period not exceeding five years, at one or more accredited nonprofit institutions of higher education selected by the student and approved by the Foundation upon its determination that the program of study in oceanography at each such institution meets standards established in regulations prescribed by the Foundation.

"(3) Each person awarded a fellowship under this subsection shall receive for each academic year thereunder a stipend of not less than $3,500 nor more than $4,000, which shall be payable in such manner and at such time or times as may be provided in regulations prescribed by the Foundation, and which shall be payable only during such period as the Foundation finds that he is maintaining satisfactory proficiency in (and devoting essentially full time to) the program of study for which the fellowship was awarded.

"(c) Notwithstanding any other provision of law, the Foundation may make grants to an institution of higher education as described in subsection (a) under an agreement providing that such grants will be made (subject to subsection (a) (5) over a period of years sufficient to permit the full development of the program set forth in its application made under that subsection, and may award fellowships as described in subsection (b) under an agreement providing that the stipends thereunder will be paid (subject to subsection (b)(3) over the full period of the fellowship.

"(d) Of the amounts appropriated for any fiscal year pursuant to section 18, not more than $500,000 shall be available for grants under subsection (a) of this section and not more than $300,000 for graduate fellowships under subsection (b) of this section."

SEC. 2. (a) Section 10 of the National Science Foundation Act of 1950 is amended by striking out "section 17" and inserting in lieu thereof "section 18".

(b) Subsection 17(b)(1) of such Act (as redesignated by the first section of this Act) is amended by striking out "section 15(h)" and inserting in lieu thereof "section 16(h)".

86TH CONGRESS
1ST SESSION

H.R. 8584

IN THE HOUSE OF REPRESENTATIVES

AUGUST 10, 1959

Mr. GEORGE P. MILLER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To amend section 4472 of the Revised Statutes to provide that the disposition at sea of certain explosives and other dangerous articles shall be subject to regulation

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"(ii) 'dangerous articles' includes, but is not limited to, radioactive, biological, and chemical substances."

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86TH CONGRESS
1ST SESSION

H.R. 8611

IN THE HOUSE OF REPRESENTATIVES

AUGUST 11, 1959

Mr. BONNER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To remove geographical limitations on activities of the Coast and Geodetic Survey, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act of August 6, 1947 (ch. 504, 61 Stat. 787; 33 U.S.C. 883a–883i), is amended by adding at the end thereof a new section reading as follows:

"SEC. 11. The Secretary of Commerce may conduct activities authorized by this Act without regard to the geographical limitations set forth herein in connection with projects designated as essential to the national interest by the head of an executive department or agency."

86TH CONGRESS
1ST SESSION

H.R. 8612

IN THE HOUSE OF REPRESENTATIVES

AUGUST 11, 1959

Mr. BONNER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To provide flexibility in the performance of certain functions of the Coast and Geodetic Survey and of the Weather Bureau

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86TH CONGRESS
1ST SESSION

H.R. 9273

IN THE HOUSE OF REPRESENTATIVES

SEPTEMBER 14, 1959

Mr. BONNER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To provide for a study of biological marine life in certain parts of the Atlantic and Pacific Oceans reasonably proximate to the Panama Canal and Central America

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86TH CONGRESS
2D SESSION

H.R. 9361

IN THE HOUSE OF REPRESENTATIVES

JANUARY 6, 1960

Mr. PELLY introduced the following bill; which was referred to the committee on Merchant Marine and Fisheries

A BILL

To advance the marine sciences, to establish a comprehensive ten-year program of oceanographic research and surveys; to promote commerce and navigation to secure the national defense; to expand ocean resources; to authorize the construction of research and survey ships and facilities; to assure systematic studies of effects of radioactive materials in marine environments; to enhance the general welfare, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Marine Sciences and Research Act of 1959."

DECLARATION OF POLICY

SEC. 2. The Congress hereby declares that systematic, scientific studies and surveys of the oceans and ocean floor, the collection, preparation and dissemination of comprehensive data regarding the physics, biology, chemistry and geology of the seas, and the education and effective fellowship program is vital to defense against attack from the oceans and to the operation of our own surface and sub-surface naval forces with maximum efficiency, to the rehabilitation of our commercial fisheries and utilization of other ocean resources, to the expansion of commerce and navigation, and to the development of scientific knowledge since many problems require an understanding of the waters which cover 71 per centum of the earth's surface, life within these waters, and the interchange of energy and matter between the sea and atmosphere.

The Congress further declares that sound national policy requires that the United States not be excelled in the fields of oceanographic research, basic, military or applied, by any nation which may presently or in the future threaten our general welfare, maritime commerce, security, access to an utilization of ocean fisheries, or the contamination of adjacent seas by the dumping of radioactive wastes or other harmful agents.

The Congress further declares that to meet the objectives outlined in the preceding paragraphs of this Act there must be a coordinated, long-range program of oceanographic research similar or identical to that recommended as a minimal program by the Committee on Oceanography of the National Academy of Sciences-National Research Council which requires but is not limited to the—

1. construction of modern, oceangoing ships for scientific research, surveys, fisheries exploration and marine development;
2. construction of laboratory and shore facilities adequate to service and supplement the research and survey fleets;
3. development and acquisition of new and improved research tools, devices, instruments, and techniques including but not limited to bathyscaphs and other manned submersibles, manned and unmanned deep ocean buoys, modified icebreakers, acoustical equipment and telemetering devices, current meters, direct density, turbulence and radioactivity measuring devices, biological sampling instruments, precision salinometers and echo sounders, magnetometers, and deep sea underwater cameras;
4. recruitment of prospective oceanographers from among undergraduate students of physics, chemistry, biology and geology and the facilitating of their advanced education in the marine sciences by a long-term fellowship program, where necessary, supported by or through the National Science Foundation or other appropriate agency of the Federal Government;
5. improvement of the economic and general welfare by obtaining more adequate information in the field of oceanography concerning the occurrence,

behavior, and potential use of fish, shellfish, and other marine life, and thereby to enhance the development and utilization of living marine resources;

6. establishment of a national oceanographic records center to assemble, prepare and disseminate all scientific and technical oceanographic and closely related data, including but not limited to physical, biological, fisheries, hydrographic and coastal survey, meteorological and climatological data. All nonclassified data shall be made available for public use; and

7. development of formal international cooperation in the marine sciences on a reciprocal basis subject to approval by the President.

The Congress further declares that a coordinated, long-range program of oceanographic research *requires establishment of a Division of Marine Scicnces in the National Science Foundation* [emphasis added], which shall include representation from Government agencies having duties or responsibilities connected with or related to the seas and oceans, and oceanographic scientists associated with universities, institutions affiliated with universities, laboratories, or foundations, and which Division shall be authorized and directed—

(*a*) to develop and encourage a continuing national policy and program for the promotion of oceanographic research, surveys and education in the marine sciences: *Provided*, That the long-range program for oceanographic research developed and projected by the Chief of Naval Research, Department of the Navy, and approved by the Chief of Naval Operations, known as project TENOC (Ten Years in Oceanography), be incorporated in the national program and policy;

(*b*) to recommend contracts, grants, loans, or other forms of assistance for the development and operation of a comprehensive national program of oceanographic research and education in the marine sciences;

(*c*) to cooperate with and encourage the cooperation of the Office of Naval Research, the Hydrographic Office, the Bureau of Ships, the Coast and Geodetic Survey, the Bureau of Commercial Fisheries, the Atomic Energy Commission, the Maritime Administration, the United States Weather Bureau, the United States Coast Guard, the United States Geological Survey, the National Bureau of Standards, and other Government agencies dealing with problems related to the seas, and the National Academy of Sciences-National Research Council, and administrators and scientists of all universities and institutions receiving assistance from Federal agencies for oceanographic or fisheries research or education in the marine sciences in the form of contracts, loans, grants, leases, donations, scholarships, fellowships, or transfers of funds or property of the Federal Government;

(*d*) to foster the interchange of information among marine scientists in the United States and foreign nations within the security provisions and limitations of the National Science Foundation Act of 1950 (64 Stat., ch. 171); and

(*e*) to evaluate the scientific aspects of programs of oceanographic and fisheries research and surveys undertaken by agencies of the Federal Government, universities and institutions receiving assistance from the Federal Government for oceanographic and fisheries research and ocean surveys.

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86TH CONGRESS
2D SESSION

H. R. 10412

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 15, 1960

Mr. GEORGE P. MILLER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To establish a public policy with respect to oceanographic surveys, and to provide for coordination of the efforts of Federal agencies with respect to oceanographic surveys

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Congress hereby finds that the needs

of the United States in the fields of navigation, commerce, fisheries, and national defense require that continuing oceanographic surveys be made of the oceans and seas of the world. Congress further finds that although there is authority for conducting these oceanographic surveys, this authority has been granted to agencies of Government in the fields of their special interest and thus coordination of effort is necessary to most effectively carry out continuing oceanographic surveys.

SEC. 2. (a) There is hereby established the Coordinating Committee on Oceanographic Surveys (hereinafter referred to as the "Committee"). The Committee shall be composed of one representative from each of the following agencies:

(1) Office of Naval Research,
(2) the Hydrographic Office,
(3) the Coast and Geodetic Survey,
(4) the Maritime Administration,
(5) the United States Coast Guard,
(6) the United States Weather Bureau,
(7) the United States Fish and Wildlife Service.

* * * * * * *

(f) In carrying out its duties under subsection (e) of this section, the Committee shall, from time to time—

(1) Assess and appraise the objectives of the United States in the field of oceanography, and

(2) Consider policies on matters of common interest to the agencies of Government concerned with oceanography.

SEC. 3. The Committee shall, not later than January 31 of each year, submit to the President and to Congress an annual report of its activities under this Act, including recommendations for any legislation which it deems necessary to carry out this Act.

86TH CONGRESS
2D SESSION

H. R. 10546

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 18, 1960

Mr. OLIVER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To establish a public policy with respect to oceanographic surveys, and to provide for coordination of the efforts of Federal agencies with respect to oceanographic surveys

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86TH CONGRESS
2D SESSION

H. R. 10581

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 22, 1960

Mr. PELLY introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To establish a public policy with respect to oceanographic surveys, and to provide for coordination of the efforts of Federal agencies with respect to oceanographic surveys

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86TH CONGRESS
2D SESSION

H. R. 10645

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 25, 1960

Mr. BONNER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To amend the Merchant Marine Act, 1936, to provide that funds of the United States may be expended for construction of certain vessels only when such construction is carried out by the Secretary of Commerce

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86TH CONGRESS
2D SESSION

H. R. 12018

IN THE HOUSE OF REPRESENTATIVES

MAY 2, 1960

Mr. GEORGE P. MILLER introduced the following bill; which was referred to the Committee on Merchant Marine and Fisheries

A BILL

To establish within the United States Coast and Geodetic Survey a National Oceanographic Data Center and a National Instrumentation Test and Calibration Center

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) the Secretary of Commerce is authorized to establish within the United States Coast and Geodetic Survey a National Oceanographic Data Center. The function of the National Oceanographic Data Center shall be to acquire, assemble, process, and disseminate all scientific and technological and oceanographic and related environmental data, including, but not limited to, physical, biological, fisheries, hydrographic and coastal survey, meteorological, climatological, and geophysical data.

(b) There is hereby established an advisory board composed of one representative from each of the following agencies: (1) the Department of the Navy, (2) the Bureau of Commercial Fisheries of the Department of the Interior, (3) the National Science Foundation, and (4) the Atomic Energy Commission. Such advisory board shall advise and consult with the Secretary of Commerce in the administration of the National Oceanographic Data Center.

(c) The National Oceanographic Data Center is authorized to conduct research and other projects within the fields of its activities for any department, agency, or instrumentality of the Government of the United States on a cost reimbursable basis.

(d) The Secretary of Commerce is authorized to exchange or sell, on a cost reimbursable basis, such data, publications, or other information of the National Oceanographic Data Center as he deems to be in the public interest. Such exchange or sale may be made with any governmental or nongovernmental department, agency, or institution or with any other person (including foreign governmental departments, agencies, and instrumentalities, and foreign persons).

SEC. 2. (a) The Secretary of Commerce is authorized to establish within the United States Coast and Geodetic Survey a National Instrumentation Test and Calibration Center. The function of the National Instrumentation Test and Calibration Center shall be to test, calibrate, and evaluate geographic and hydrographic instrumentation. Such testing, calibration, and evaluation shall be done on a cost reimbursable basis, and may be done for any governmental or nongovernmental department, agency, or institution or for any other person (including foreign governmental departments, agencies, and instrumentalities, and foreign persons).

86TH CONGRESS
1ST SESSION

S. 2692

IN THE SENATE OF THE UNITED STATES

SEPTEMBER 11 (LEGISLATIVE DAY, SEPTEMBER 5), 1959

Mr. MAGNUSON (for himself, Mr. SMATHERS, Mr. SCHOEPPEL, Mr. BARTLETT, Mr. YARBOROUGH, Mr. CASE of New Jersey, Mr. ENGLE, Mr. SCOTT, Mr. MCGEE, Mr. BUTLER, Mr. HART, Mrs. SMITH, and Mr. CLARK) introduced the following bill; which was read twice and referred to the Committee on Interstate and Foreign Commerce

A BILL

To advance the marine sciences, to establish a comprehensive ten-year program of oceanographic research and surveys; to promote commerce and navigation, to secure the national defense; to expand ocean resources; to authorize the construction of research and survey ships and facilities; to assure systematic studies of effects of radioactive materials in marine environments; to enhance the general welfare; and for other purposes

* * * * * * *

Senator Magnuson had said in opening his hearings on the omnibus bill: "Undoubtedly this bill, like most legislation when first drafted, can be improved as a result of advice and counsel obtained during the course of these hearings, but I submit that the basic purpose of the proposed measure must stand. That purpose is to assure the United States a fund of scientific knowledge of the oceans, their estuaries, and the Great Lakes second to that of no other nation, to provide the facilities for obtaining that knowledge, and to encourage the education and training of an adequate number of scientists and technicians to assemble that knowledge and to make maximum use of it after it is obtained."

In the course of the hearings by the various committees having jurisdiction over these bills, there developed a pattern of almost unanimous support by the scientific community, and almost monolithic opposition by administration witnesses.

Although agreeing with the objectives, those opposing the bills noted that adequate statutory authority exists by which a national program, yet unspecified, can be developed by the various individual agencies having cognizance over the various segments. Those opposing the bills further stated that coordination can be effected by the Interagency Committee on Oceanography of the Federal Council for Science and Technology. Some witnesses went further by opposing any Government policy which singles out particular fields such as oceanography for special legislation, because of what they believed would be an imbalance of an otherwise carefully proportioned program involving all fields.

Both the executive branch and the scientific community, however, noted that the present bills appeared far more specific in enumerating details of program and mechanism than may be in the best interest of oceanography. In general they pointed out that any long-range program needs flexibility, and this may be denied the program if the statutory basis introduces unnecessary rigidity through detail. At this writing, the only action completed was by the Senate Interstate and Foreign Commerce Committee favorably reporting out on June 7, 1960 an amended version of S. 2692, the omnibus bill which provides

a statutory base for coordination of oceanography by the National Science Foundation.[106]

The 86th Congress is thus confronted with a number of issues; some of these may be resolved during this session, but some are far broader than oceanography alone. In this sense, oceanography may represent the first of what may be identified as special scientific and technical fields that for one reason or another have been neglected in relation to national needs for the future security and well-being of the country, ultimately either for military or for nonmilitary application. Any course of action taken for oceanography may be regarded as some sort of precedent, for with the exception of atomic energy and outer space, the Congress has not recently taken legislative action concerning one special field of science.

[106] This bill was approved by the Senate on June 25, 1960 and referred to the House Committee on Merchant Marine and Fisheries.

XIII. Issues Before the Congress

A. IMMEDIATE ISSUES

The vital relationship of the oceans to our national security has been widely enunciated by scientific, military, and political leaders. Considering the exceedingly small effort devoted to oceanographic research and considering the need, increased understanding of the seas has been deemed urgent:

(*a*) for increased defense against enemy submarines;

(*b*) for the effective operation of a Polaris program as a major element in policy of deterrence;

(*c*) for the rehabilitation of commercial fishing;

(*d*) for utilization of ocean mineral resources;

(*e*) to facilitate commerce and navigation;

(*f*) to expand scientific knowledge of the planet on which man lives, including the phenomena in which the oceans affect climate and weather.

The known expansion of Soviet effort in this field almost certainly assures their surpassing the United States in a few years. In view of past exploitations by the Soviets of scientific achievement for purposes of propaganda, they may be expected to use research in the sea for the same purpose.

In this context, a number of immediate issues confront the Congress:

1. The Congress may thus wish to establish a sense of purpose and unity to a national program in oceanic research.

2. If the Congress concurs with the analyses by the National Academy of Sciences and others, it may wish assurance that such a program is being planned for expansion on a long-range basis with due consideration for technical content, increased manpower, increased facilities, necessary funding, and adequate management and coordination.

3. The question arises as to whether existing statutory authority is sufficient to implement such a program.

4. If statutory authority is deemed adequate, then the Congress may wish to assure itself that this program is being implemented with sufficient vigor, funds, and leadership to establish the posture required for national security.

5. In that regard, the question may well be raised as to whether present coordination under the President's Federal Council for Science and Technology is proper and adequate.

6. There is a separate question of balance between Government and non-Government funding for oceanographic research and between civilian and military orientation. In regard to the former, it is clear that the incentives for private capital are insufficient compared to the risk. The question then develops as to what incentives could and should be provided by the Federal Government that will reduce the burden of Federal sponsorship now visualized.

7. With regard to military versus civilian balance, the greatest proportion of Federal support now comes from the Navy Department. The Navy's responsibilities with regard particularly to antisubmarine defense make it clear that they must have a heavy and continuing interest in oceanic research. However, the civilian aspects of research are linked strongly to our national security in terms of domestic economic strength and in terms of continued international leadership. There appears to be agreement that the nonmilitary programs of basic and applied research in oceanography may outstrip the military programs. There is thus a question as to where leadership for a broad national program should be vested.

8. If existing statutory authority is deemed insufficient, what form of new legislation is required? Analysis of current problems focuses priority attention on the elements of a unified program and related interagency coordination.

B. EMERGING ISSUES

The Congress now has before it a number of pending bills concerned specifically with oceanic research. It is recognized, however, that this field represents but one of many requiring special emphasis or support in terms of contemporary events. Moreover, there is an awakened recognition that science and technology generally are playing an increasingly significant role in domestic and international affairs. There is thus reason to examine certain of the issues confronting the program in oceanography in the broader context of problems facing the national program of research. These broader issues may be phrased as questions:

(1) What now constitutes a national policy regarding science and technology? How have these policies been formulated, and what provision is made for a continuing attention to establishment of policies that can serve as a frame of reference when evaluating specific items of proposed legislation?

(2) Is a new pattern of Federal organization necessary to accommodate the emerging demands for Federal operations in the field of science and technology?

(3) When specific fields are identified as neglected and, for reasons of national security, in need of stimulation, what measures should the Federal Government take regarding manpower, facilities, funds, and organization?

(4) What national policies can be established that will motivate interest and investment on the part of private industry to engage in or otherwise foster basic research?

XIV. Committee Conclusions and Recommendations

The committee endorses the foregoing study for its completeness, and care of preparation, and for its attempt to provide objective analysis including the identification of major issues, together with the arguments pro and con of principal groups in and out of Government concerned with our progress in the ocean sciences. The study has had the benefit of careful independent review by several specialists.

Because the committee's hearings on this subject have been relatively brief, in contrast with this study which is one of the most comprehensive ever prepared, the conclusions of the committee are necessarily qualified for the present, when it comes to certain specifics which seem to flow from this report.

The numbered conclusions given below are stated in positive terms where they represent the consensus of virtually all reviewers of these problems in and out of Government. In other cases where the conclusions or recommendations may also be valid, and there is strong but not unanimous support among all scientists, military authorities, and Government officials, the conclusions have been worded to show such qualification, or they recommend further study by the appropriate authorities in the legislative and executive branches of Government, the scientific community, and other interested persons.

Accordingly, the conclusions and recommendations of the committee are as follows:

1. The sea, which has historically served the United States both as a geographical barrier against aggression and as a medium of commerce, has become increasingly important in terms of political, economic, and scientific factors as an element of national security.

2. Yet the sea, which represents 71 percent of the Earth's surface, is mostly unexplored. Scientific information is meager concerning the physical and chemical properties of oceans and their currents, the biological and mineral resources of, in and under the sea, the relationship of the oceans to weather and climate. Even knowledge about the origins of the oceans themselves, their evolution and the changes which may be expected are little known and understood.

3. Biological resources in the sea may supplement protein for human nourishment in a burgeoning growth of population. Mineral resources may answer future technological demand when resources on the continents may be depleted or economically unfeasible to extract. Understanding of the Moon, of outer space and of extra-terrestrial phenomena far more remote from human endeavors presupposes knowledge of our own planet, yet this is not the case, and clues to geological and geophysical processes may well be found by studies in and under the sea. Safety of radioactive waste disposal presupposes knowledge of ocean currents and biological activity.

4. That the sea is opaque to light and other electromagnetic radiation so as to conceal its contents manifestly describes the core of Soviet submarine threat to continental United States. The oceans may hide

hostile vehicles that could glide or crawl undetected near enough to our shores as to place much of the Nation's industrial strength within range of submarine-launched missiles. Moving quietly and leaving the scantiest of trace, the problem of detecting, classifying, and tracking such vehicles poses one of the most serious challenges to our antisubmarine defenses.

5. In view of the threat manifested by the Soviet submarine fleet, it is essential as an element in antisubmarine warfare to develop knowledge leading to means for complete surveillance of the oceans, thus to minimize the possibility of a surprise attack from under the sea.

6. By virtue of the lack of knowledge of the sea, concerted and systematic research may be expected to produce an unusual number of breakthroughs. Not to pursue research in the oceans at a sufficient pace may deny the United States those opportunities for discovery and even more seriously may offer other nations the advantage of surprise in that exploitation.

7. The Soviet Union has accelerated its effort in oceanographic research, in what may be a deliberate attempt to overtake and surpass oceanography in the United States. Scientific achievements in this field would provide ample potential for propaganda, which, following its actions in outer space, the U.S.S.R. may be expected to pursue.

8. Both in and out of Government, it is the general view that the present level of scientific effort and inventory of ships and shore facilities are evidence that this field has been badly neglected. This deficiency first identified 30 years ago has prompted three independent studies in 1927, 1949, and 1957, each identifying significance of the oceans, and urging development of a national program with continuity of financial support that would permit a steady progress toward scientific goals. The latest of these, developed by the National Academy of Science's Committee on Oceanography, presented an exceedingly thorough and clear status of the present posture in oceanography, and proposed a 10-year program by which national interests could best be served.

9. This committee concurs with the general intent of the National Academy of Science and Navy proposals for a bigger program in the ocean sciences, and is open to persuasion that the level of effort in oceanography must be increased by a factor of four over the next 10 years, measured in terms of numbers of participants, and level of funding. Even then, the annual expenditures for research in the oceans would approach only a small fraction of appropriations in fiscal 1961 for research in other important fields.

10. Such expansion can be achieved without the problems and waste that attend a crash program, if long-range systematic and coordinated planning is developed on a national basis and properly implemented. In this regard, it is clear that the Federal Government already is the major sponsor of oceanic research and that the role of the Federal Government in such sponsorship will increase in the future.

11. It is, therefore, incumbent upon the Federal Government to be sure that its program has unity, a sense of purpose, coordination, and vigor to be sure that the goals are met effectively and with due regard to thrift.

12. The statutory basis for Federal programs in oceanography has existed for some time and especially since inauguration of the Office

of Naval Research in 1946 and the formation of the National Science Foundation in 1950. Nevertheless, examination of the Navy and National Science Foundation programs in oceanography reveals that until fiscal 1960, in the view of many observers they appeared lacking in emphasis, vigor, and adequacy of funding. Responsible officials of the executive branch as well as legislators have called for a new effort in this regard. The Navy, until recently, has not pursued a broad program in oceanography, despite its relevance to the Navy's antisubmarine mission; and this has been true even though the Navy is now the largest single supporter of such research.

13. Other civilian agencies of Government having jurisdiction in the ocean sciences have also not moved spontaneously to fulfill the potential that lies in research in the sea. Moreover, this committee is sympathetic to the view that future expansion of research in the oceans should be concentrated more heavily in the civilian agencies than in the military, for reasons detailed in the accompanying report.

14. Most information about the sea concerns the surface or the boundaries. Much, therefore, remains to be discovered in and at the bottom of the deep oceans. The United States assumed a position of world leadership in use of manned vehicles essential for deep exploration of the ocean through the purchase of the bathyscaph *Trieste*. There is question whether U.S. Navy has provided adequate logistic support for the *Trieste* program and is fully utilizing this facility for scientific exploration. Moreover, since the *Trieste* has limited mobility and endurance and is delicate to maneuver at sea, new types of manned vehicles with enhanced capabilities are necessary for a broad attack on the oceans, and the Navy should be offered every encouragement to pursue promptly such a course of development.

15. It is thus apparent that although the statutory basis has and now exists for a national program in oceanography, such a program has not yet emerged as an operating reality. This committee suggests that the major reason for its absence is the highly diffused responsibility for various sectors of research in the sea throughout a large number of Government agencies, and (at least in the past) the absence of effective coordination.

16. The Interagency Committee on Oceanography has been operating too short a time to evaluate its effectiveness. Actions thus far to implement interagency coordination and accelerate a national program are to be commended. However, weighing its strengths and weaknesses, it is believed it may be handicapped in ultimately achieving its goals by lacking statutory basis.

17. To remove the disparity between the current level of effort and the needs for national security, it is necessary that the Federal Government organize, manage, and coordinate the necessary program. This responsibility entails:

(*a*) The development of a national program in oceanic research and identification of goals.

(*b*) The budgeting of funds for a balanced program embracing all elements of oceanic research both for peaceful and military applications.

(*c*) The implementation of such a program by both in-house and contract research.

(*d*) The deliberate fostering of education and training in the field of oceanography so as to assure an increasing flow of manpower without prejudice to other fields of science.

18. A major study is deemed necessary of Federal organization for oceanographic research. The question should be explored whether at this time, the objectives of program planning and coordination would be best accomplished by the formation of a new, separate agency, having responsibility to coordinate all elements of the program. Conduct of research and surveys, however, probably will be continued by certain and perhaps all of the Government agencies now having jurisdiction over particular sectors so as to assure prompt and effective application in their fields of cognizance.

19. The coordinating agency might solicit guidance from two sets of advisory committees: the first composed of senior representatives from those Federal agencies having jurisdiction over various segments of the program to advise on operations, division of responsibilities, and coordination; and the second comprising members of the scientific community to evaluate and advise on program content. The Committee on Oceanography at the National Academy of Sciences would appear well suited for this latter function.

20. Because of the urgency for an enriched national program in oceanography, funding almost certainly will be initially provided by the Federal Government. American industry and commerce, however, are beneficiaries of results from basic research, generally, including those from oceanic research. The new agency being considered might establish still a third committee, including participants from industrial concerns, private foundations, etc., to examine means by which private capital and endowments could be attracted for the sponsorship of research in the oceans so as to be an effective partner with the Federal Government in the development of this program.

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